

PROPERTIES OF THE
"GUGLER PRIMARY BATTERY"

BY
A. A. PERRINE

ARMOUR INSTITUTE OF TECHNOLOGY

1912

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Experimental determination
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AN EXPERIMENTAL DETERMINATION OF THE PROPERTIES

OF THE

"GUGLER PRIMARY BATTERY"

A T H E S I S

PRESENTED BY

ARTHUR A.R. PERRINE

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE

OF

ELECTRICAL ENGINEER.

MAY 1912.

Approved
E. N. Freeman

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Dean of Coll. Studies

J. M. Raymond

Dean of Eng. Studies

AN EXPERIMENTAL DETERMINATION OF THE PROPERTIES

OF THE

"COOLER PRIMARY BATTERY"

A T H E S I S

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CALIBRATION OF INSTRUMENTS.

Calibration of Instruments.

The instruments used to measure the current and voltage for these tests were Weston Volt-meter Model 45 #6093 and Weston Milli-volt meter Model 45 #5792 with one and ten ampere shunts.

It was deemed advisable to calibrate the instruments used by comparing them with a standard instrument known to be correct on account of the tendency of electrical instruments to read incorrectly after a time by reason of their construction or due to mechanical injury.

Each instrument was calibrated both before and after the test and an average value taken from the calibration curves in place of the observed readings. These average values were used in plotting curves and making calculations. The original data as read directly from the instrument was not recorded.

The calibration curves using the average values follow:

Calibration of Instruments.

The instruments used to measure the voltage and voltage for these tests were Weston Voltmeter Model 45 (0-150) and Weston Voltmeter Model 45 (0-150) and two other meters. It was deemed desirable to calibrate the instruments used by comparing them with a standard instrument known to be correct on account of the tendency of electrical instruments to read incorrectly after a long period of their construction and use in electrical testing.

Each instrument was calibrated both before and after the test and an average value taken from the calibration curve at each of the observed readings. These average values were used in plotting curves and making calculations. The original data as read directly from the instrument was not recorded. The calibration curves were plotted and the average values obtained.

Calibration of Volt meter #5060.

Tested Standard Volt meter (2-5) #5060. Volt meter #5060.
(2-3) #5060.

.1	.1
.32	.32
.3015	.3005
.43	.43
.492	.51
.564	.578
.608	.63
.835	.834
.938	.89
.989	.998
1.091	1.13
1.182	1.2
1.368	1.36
1.545	1.545
1.626	1.63
1.685	1.7
1.779	1.8
2.	2.
2.193	2.2
2.393	2.3
2.582	2.59
2.753	2.74

Temperature of Standard instrument 23.7 C.

Calibration of Weston Milli-Volt meter.

#5792 with one ampere shunt.

Laboratory Standard-Milli-Volt meter #342 and 1.5 ampere shunt #4977.

Ammeter #5712.

.1	.1
.2	.2
.3	.301
.4	.402
.5	.503
.6	.603
.7	.705
.8	.804
.9	.902
.996	1.000

Temperature of Standard Instrument 24.52 C.

Calibration of Weston Milli-Volt Meter

#5732 with 10 ampere shunt.

Laboratory Standard Milli-Volt meter #242 and 15 ampere shunt #4977.

Meter #5732.

1.	1.
2.	1.99
3.	2.99
4.	3.99
5.	4.99
6.	5.99
7.	6.99
8.	7.98
9.	8.98
10.	9.98

Temperature of Standard Thermocouple 24.5° C.

Table 1. Results of the first trial.

Table 2. Results of the second trial.

Table 3. Results of the third trial.

Table 4. Results of the fourth trial.

1.0	1.0
0.9	0.9
0.8	0.8
0.7	0.7
0.6	0.6
0.5	0.5
0.4	0.4
0.3	0.3
0.2	0.2
0.1	0.1
0.0	0.0

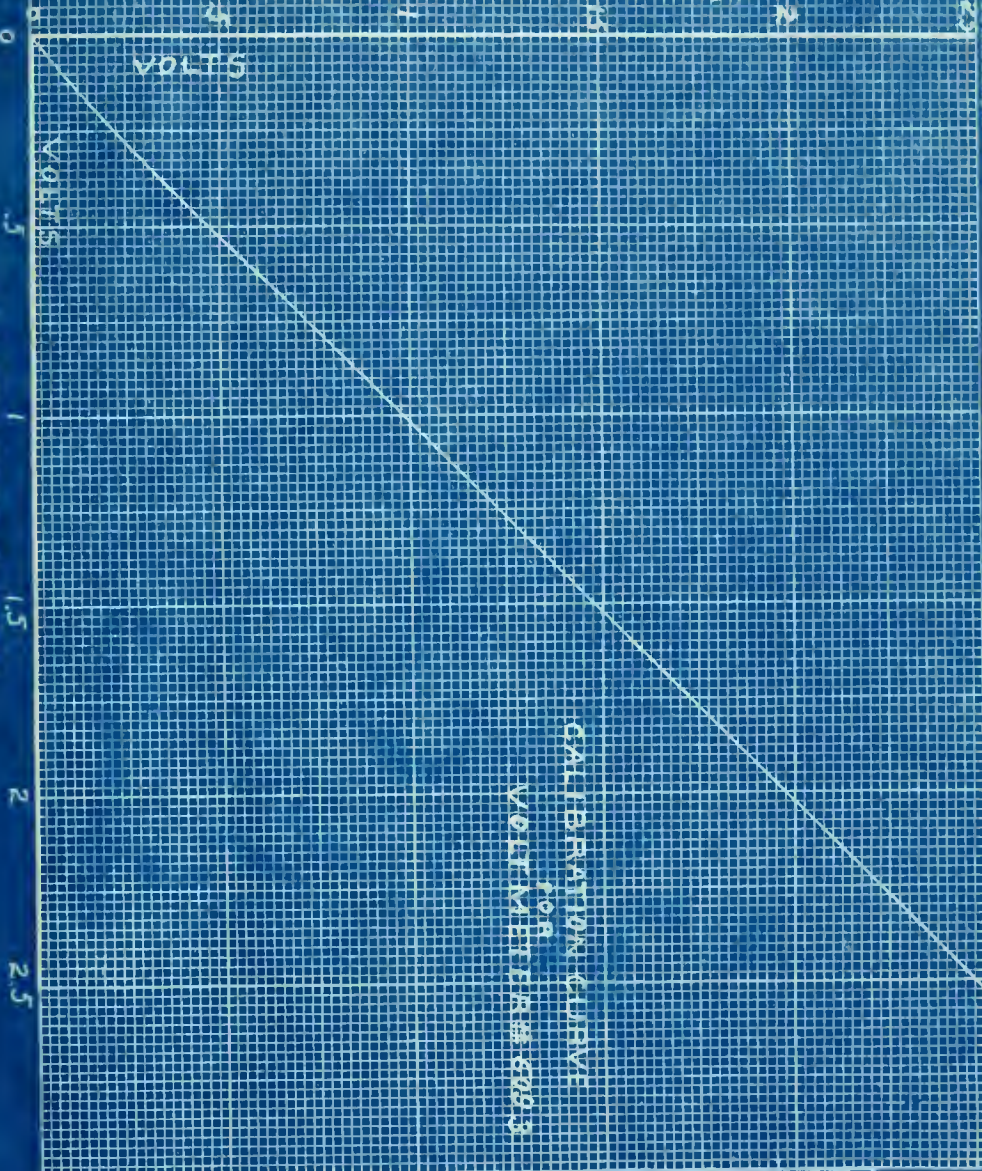
Table 5. Results of the fifth trial.

STANDARD VOLT METER # 6083

Volts

Volts

VOLT METER # 6083

CALIBRATION CURVE
FOR
VOLT METER # 6083

STANDARD AMMETER #242

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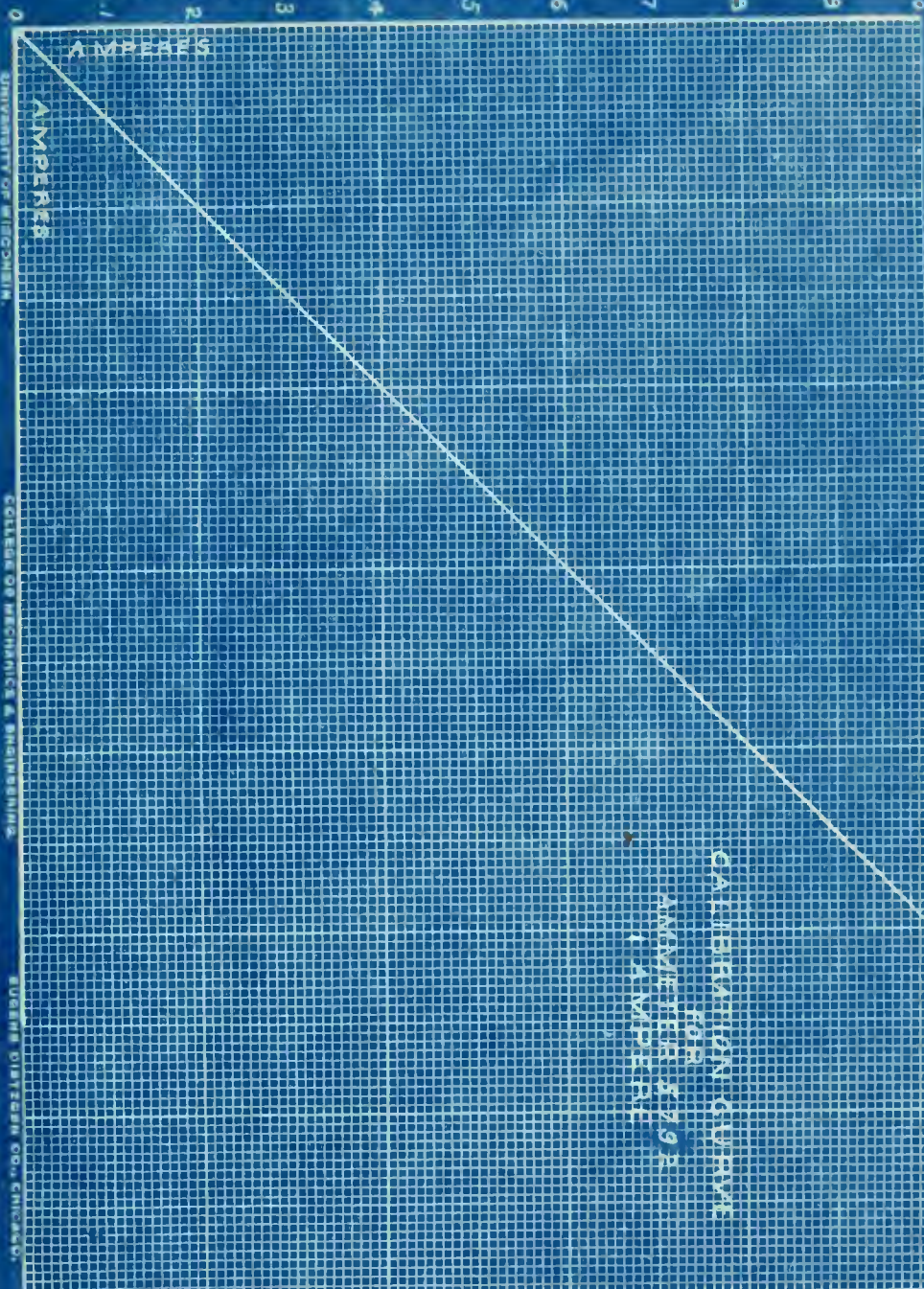
EUGENE DITZGEN CO., CHICAGO

AMPERES

AMPERES

AMMETER #5792

CALIBRATION CURVE
FOR
AMMETER #5792
1.5 AMPERES



AMMETER # 242 STANDARD

AMPERES

CALIBRATION CURVE

FOR
AMMETER # 5792
10 AMPERE

UNIVERSITY OF WISCONSIN

COLLEGE OF MECHANICAL ENGINEERING

EUGENE DIEZELER EQUIPMENT

AMMETER # 5792

Primary electric batteries have had a very bad reputation for supplying any but small currents. This is very unfortunate, as the primary battery in its proper place is an extremely useful and convenient generator of electricity. The primary battery was well known before the advent of the dynamo, but the latter has made such wonderful strides that its predecessor, the primary battery, was greatly neglected.

The principal reasons why the primary battery has had such a bad reputation, seem to be, because so many batteries were brought out which were false and mere impositions on the public; and that a great many inventors and promoters have neglected and tried to obscure the important question of the cost of the materials which are consumed in their batteries, leaving the users to find this out for themselves; and thirdly the mechanical construction of primary batteries, to deliver large currents but generally being very bad, they were irrationally proportioned, hard to handle, were very difficult to keep clean, and the process of filling and emptying was tedious and slow.

In principle, the primary battery is a more efficient converter of chemical energy into electrical energy than the steam or gas engine driven

dynamo. This great advantage is more than counter-balanced by the fact that the fuel consumed by the primary batteries is much more expensive than that used in steam engines. Yet while this is true for the production of large quantities of electrical energy, it is also true that for the production of smaller quantities of electrical energy the primary battery has quite an advantage in regard to economy of cost over the installation of an engine and dynamo plant.

It is the primary purpose of this investigation to bring out the more important points in the behavior of the Gugler Primary Battery. To this end four cells were tested, three potassium chlorate cells and one "blue stone" cell. In order to have the conditions of the test as near as possible to those under which the batteries must operate in practice: the electrolyte was prepared with ordinary tap water and the cells were placed in a room of which the temperature would be about normal. Although the average temperature was a little low, it was about as good as could be secured without artificial heat and this was not deemed expedient.

The cells submitted for the test were of temporary construction, Mr. Gugler having certain changes in design of parts to complete before the

cells will be placed on the market. These are minor details and consist merely of a porous cup with an angular grooved bottom to reduce the quantity of mercury and a suitable cell cover.

The Gugler cell has not been marketed for signal service although cells of this type have been on continuous discharge at the Western Union Telegraph Co., for more than twenty months on one charge. The cell shows possibilities of large cost advantages over the "Blue Stone" and "Magnetic Rods" types of cells commonly used on signal service.

Before assembling the cells each part or element was carefully weighed and recorded. The weights of each cell will be found under "Weights of Component Parts of Cells". After assembling the cells, each cell was labeled and will hereafter be referred to as No. 1, No. 2, No. 3, and No. 4. At the recommendation of Mr. Gugler, cell No. 1 was discharged through a constant resistance starting at approximately twenty-five amperes by adjusting resistance to secure this after cell had been in operation two hours. Cells Nos. 2 and 3 were discharged through a constant resistance on separate circuits once every two minutes for a period of ten seconds starting at approximately 2.9 amperes which is the normal current consumption of

a selenophore. Cell No. 4 was the common copper sulphate or gravity cell. This cell was merely tested to secure comparative data. The discharge being through a permanent resistance and at a current rate of approximately .5 amperes at the start. Each test will be explained in detail with the accompanying data and curves independently of the other tests.

HISTORY OF THE PRIMARY BATTERY.

In the year 1767 Sulzer prepared an address which was read before the Academy of Sciences at Berlin, in which he announced the discovery that when two pieces of metal, one of lead and the other of silver are placed together upon the tongue in such a manner that their edges are in contact a peculiar taste is perceived. The importance of Sulzer's observation was not appreciated until Galvani had made his important discovery that freshly prepared frogs' legs when suspended by a copper wire above an iron railing, twitched convulsively whenever a portion of the leg touched the iron; and Volta had demonstrated that this phenomenon was not due to the presence of animal tissue but due to the metals themselves. Giving rise to Volta's contact theory of electrical excitation which ascribes what is now known as the "difference of potential" exhibited by two metals due to a simple contact and not depending upon the medium in which they are immersed.

During the same year that Galvani's famous work appeared; Gabroni described experiments which he had made with metals that he had plunged into water and said he was satisfied that a chemical action had taken place and that it was the slow combustion and

oxidation of the metal which gave rise to the new stimulus.

The fact that the difference of potentials, resulting from a single pair of metals dipping into an aqueous liquid, can be thus multiplied by arranging in order a number of such pairs connected together, was discovered by Volta in 1800. In order to produce the effect in a marked degree, he arranged a number of alternate layers of zinc and copper; each pair of metals being separated from the next by a cloth soaked with acidulated water. The above arrangement Volta called his "electro-motive apparatus", but is more familiarly known as Volta's Pile.

A pile of this kind when composed of twenty or more of these pairs of plates produces an appreciable physiological effect when the terminals of the pile are placed upon the tongue.

This pile lead to the development of Volta's "crown of cups" which was the first real voltaic battery or device which would produce a continuous flow of electricity. This device consisted of a series of glasses or cups placed in a circle; plates of copper and zinc were connected and arranged so that a plate of zinc was placed in one cup and a plate of copper in the next.

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The oldest battery of commercial importance, which does not have a depolarizer is the Smee, developed in 1840. This cell has a positive plate of zinc and a negative plate of thin silver, corrugated and covered with platinum. The purpose of this roughened surface was to facilitate the dislodgement of the hydrogen which is released at this plate. The exciting liquid used in this cell was sulphuric acid.

Amalgamation of the zinc was introduced by Sturgeon in 1830. The two-fluid type of primary cell with porous cup to separate the fluids was invented by Daniell in 1836. Grove, in the same year, introduced the use of nitric acid as an electro-negative fluid more powerful than the copper sulphate of the Daniell's cell. Grove used a platinum negative plate to withstand the action of the nitric acid, and in 1842 Bransen substituted carbon for this expensive metal. Poggendorf in the same year devised a single-fluid cell in which a solution of potassium bichromate mixed with sulphuric acid was used as a depolarizer instead of the nitric acid of Grove, thereby avoiding the obnoxious fumes without material sacrifice to power.

Most of the batteries which have been developed since the Daniell cell are modifications of it in some

form, either of its elements, its liquids or the depolarizer used.

In the primary battery designed and constructed by Mr. Giegler during the past year, a cylindrical electrode of carbon is used for the positive element surrounded by annular carbon filling most of the space in the jar outside of the carbon element and a cylindrical sheet of zinc placed in the porous cup. Two pounds of mercury are used in this inner cup to make contact with the negative electrode. The electrolyte used for both the outer and inner solutions was sulphuric acid.. Potassium chlorate was added to the outer solution for the depolarizer.

THEORY OF THE VOLTAIC ELEMENTS.

When commercial zinc is dipped into diluted sulphuric acid it is dissolved forming zinc sulphate and liberating hydrogen. During the time that the zinc is being dissolved considerable energy is liberated in the form of heat.

If chemically pure zinc is dipped into diluted sulphuric acid very little action takes place and the small quantity of liberated hydrogen remains attached to the zinc plate protecting it from further action of the acid.

If now a plate of pure copper is dipped into the solution with the plate of pure zinc without touching, no apparent action ensues, but if wires of copper or other material are attached one to each plate, they are found to differ in potential. If the wires are now connected to the alternate terminals of a quadrant electrometer a deflection is produced indicating a difference of potential of approximately one volt, the potential of the wire connected to the copper plate being the greater.

Results similar to the above would be obtained if almost any two metals are used in place of the copper and zinc in the above experiment, and ordinary water which contains a small quantity of zinc salt in solution. The only difference in the result would be in the magnitude of the potential observed.

If now the wires are connected a vigorous action ensues, the zinc being dissolved and hydrogen is now rapidly liberated from the copper plate.

Clausius advanced, for an explanation of the action within the electrolyte of a cell; the idea that the ions of any molecule are not always linked to one another but that a continual interchange of partners, as it were, takes place between like atoms of different molecules. Thus, in a solution of sodium chloride, the sodium and chlorine of any molecule do not long remain attached to each other, the sodium changes place with the sodium of a second molecule and the chlorine may change place with the free chlorine of a third molecule. This interchange is continually going on at random as long as no outside directive force is applied. Each atom while in the free state, between successive pairings, carries a positive or negative charge of electricity.

If we assume with Verhulst that each metal (or electrode) has a specific attraction for electricity, and therefore for the ionic charges, it would be assumed that zinc attracts a positive charge less forcibly and a negative charge more forcibly than copper does. Consequently when plates of copper and zinc are immersed in sulphuric acid, there is an attraction of the negative SO_4 towards the zinc.

As this interchange of ions takes place they will be drawn to one or the other of the attracting plates, where they will be deposited, giving up their respective charges of electricity. This action continues until it is arrested by the repulsion of the respective charges accumulated on the plates. Only infinitesimal chemical action now takes place until electrical connection is made between the zinc and copper plates. Negative electricity then flows toward the copper plate and unites with the positive charge of the hydrogen atoms which moves toward the copper plate to meet the negative current. Thus the hydrogen gas is liberated at the copper plate. A stream of hydrogen atoms will move steadily in the same direction, probably by successive molecular interchanges and deliver their charges of electricity to the copper plate. This action will continue even after the external circuit is broken, until the separated electrical charges which quickly accumulate check the movements of the disengaged atoms by repulsion of like charges, and all chemical activity ceases. This condition of electrostatic equilibrium is the condition of open circuit. The two electrodes will then be found to be oppositely charged and will exhibit a difference of potential.

The chemical action which takes place in a cell on open circuit, tending to reduce its available potential energy, or going on when the circuit is closed and which does not contribute toward the production of useful current, is called local action. This action is always present when commercial zinc is used, and is due to impurities of a conducting nature; as soon as these particles are exposed to the electrolyte, a local circuit is formed with the zinc, causing the zinc to be eaten away in small pits.

To prevent this wasteful action, the surface of the zinc is amalgamated with mercury. This is best accomplished by dipping the zinc into diluted sulphuric acid to remove dirt or grease and then washing with mercury.

This amalgam serves to bring to the surface more zinc leaving dislodged impurities behind. These impurities are gradually dropped to the bottom of the cell, thereby preventing the wasteful action of local currents. This amalgam of zinc with mercury does not entirely prevent local action but it reduces it to a very small value as compared to the value the local action would have if mercury was not used.

POLARIZATION AND DEPOLARIZATION.

When a simple element, consisting for example of zinc and copper in diluted sulphuric acid, is allowed to generate a current, hydrogen is evolved at the copper plate. A small amount of this hydrogen adheres to the surface of the plate giving rise to an electromotive force which opposes that of the cell. Consequently, the E. M. F. of the cell diminishes as soon as a current is generated. This decrease of potential of the cell increases with an increase of current flowing. In addition to a reduction of the E. M. F. of the cell due to the decomposition of the electrolyte, the formation of hydrogen is also objectionable in that it forms in a layer on the surface of the cathode, thereby greatly increasing the internal resistance of the cell. This formation of hydrogen upon the surface of the cathode is called polarization.

The removal of this free hydrogen from the surface of the cathode by any means is called depolarization, and the removing agent, the depolarizer. It may be removed mechanically by agitating the electrolyte or by temporarily removing the cathode from the electrolyte when the cell is not in use. The chemical method is the most common method of depolarization used, and consists in placing some substance at or near the surface of the cathode with which the free hydrogen may unite, the energy which

is liberated by this formation may be added to the E. M. F. of the cell.

Batteries may be classified as open circuit batteries and closed circuit batteries depending upon the extent to which polarization is prevented. A closed circuit battery is one which is capable of working on a closed circuit having a moderate value of resistance for a considerable period of time, with but a slight diminution in the value of the current. The closed circuit battery is thus clearly differentiated from those cells that are adapted to give current only at short intervals of time, and that can stand on open circuit without wasteful local action.

The cell under test is of the closed circuit type, in which polarization is eliminated. Depolarization is accomplished in this cell by the use of potassium chlorate according to the following chemical formula.



This formula would be varied slightly depending upon the amount of acid in solution. If an excess of H_2SO_4 is added an unstable compound of chlorine would be formed and free chlorine or some chlorine gas may be given off.

1. The first part of the report is devoted to a general survey of the situation in the country.

2. The second part is devoted to a detailed study of the various branches of the economy.

3. The third part is devoted to a study of the social and cultural life of the country.

4. The fourth part is devoted to a study of the political situation in the country.

DESCRIPTION OF THE CELL.

The cells tested were made by The Battery Company of Milwaukee, Wisconsin and called the "Gugler Primary Battery"

The cells were all of one type and consisted in brief of an outer containing jar of glass for holding the electrolyte, depolarizer, carbon cylinder, granular carbon, syphoning tube and inner porous cup. This porous cup contains the zinc element with its terminal: contact being made between the terminal and zinc by means of mercury. The cup is filled to one-half inch of the top with the same electrolyte as was used in the outer containing jar.

The different parts entering into each completed cell were as near a duplicate of each other as they could be commercially made. The weights of the parts entering into the construction of the cells is tabulated for each cell under "Weights of Elements Composing Cells"

The glass containing jar was 3.5 inches in diameter and 11.875 inches high and made of material approximately .21 of an inch thick. The bottom of the jar at one point is formed into a small pocket so that all the electrolyte will drain down into this

little pocket as the cell is drained. The total capacity of the glass is 595.54 cubic inches and the volume of a vertical section of the jar one inch in height is 50.7 cubic inches.

The large carbon cylinder used was 9.75 inches high and had a diameter of 6.25 inches. The thickness of the material forming it was .875 inches. A small cylindrical projection from the top of carbon of a diameter of approximately 1.5 inches with a reduced diameter at its top forming a shoulder forms a contact lug. On this reduced portion a metal cap is cast of an expanding alloy which firmly binds the carbon in cooling. Over the metal cap a glass cap is placed which rests on the shoulder of the carbon lug and is made tight with a compound between the glass and carbon joint. The glass cap is larger internally than the metal cap and this space is filled with a mineral oil which effectually prevents osmosis and electrolysis between the carbon and metal couple. The glass cap has an axial perforation with a ground boss. On top of this cap another glass cap is placed in an inverted position forming a cup. Through this glass cup and cap a sleeve connector with a threaded stud on one end is passed and is drawn down tight by screwing in a threaded hole in the metal cap. The

abutting glass cups being ground and rubbing material is required to make an oil tight joint. The inverted cup which now serves the purpose of a cup is filled with oil and thus all contacts to the carbon element are submerged in oil and are proof against corrosion.

After inserting a glass tube .5 inches in diameter and .11 inches long into the pocket in the bottom of the glass jar, nine inches of the cavity between the surface of the jar and the carbon electrode is filled with a granular carbon ranging in size from that which will go through a screen having a mesh of .25 inch square for the first seven inches and for the last two inches a size that will go through a screen having a .375 inch mesh.

The porous cup is of unglazed earthenware about .186 inches thick and 4.186 inches in diameter and 10.75 inches high. It contains the zinc element, mercury and terminal wire. Connection with the zinc electrode is made by means of a copper wire dipping into the mercury pool. This copper terminal is made of No. 14 insulated copper wire encased in a glass tube and an outer casing of hard rubber tubing and terminates in an enlarged area .375 inches in diameter.

The zinc element of the cell is in the form of a cylinder 7.75 inches high and having a diameter of 3.5 inches and formed of material .1875 inches thick by rolling from a flat plate leaving a cleft of approximately one half inch in the surface of the cylinder.

The cell is set up in the following manner. After washing the glass jar, zinc and porous cup to remove dirt or other impurities, the carbon cylinder is placed in the glass containing jar. The glass tube for draining off the outer solution is inserted in the pocket of the glass jar, then the remaining space between the carbon cylinder and the glass jar is filled with granular carbon which has ^{an} approximate size of .25 inches, until an approximate height of 7 inches is secured, then about 3 inches of coarse carbon having a size of about .575 inches is added. One pound of potassium chlorate is then placed on top of the granular carbon.

The porous cup was now placed in the center inside of the carbon cylinder, and two pounds of mercury was poured into it. The zinc electrode with its terminal was then placed in the cup.

In order to make the test conditions as near as possible to what they would be in practice

The same amount of the salt is to be used in
a cylinder 7.75 inches high and having a diameter of
3.5 inches and low end of material. 7.75 inches thick
on rolled from a flat plate having a width of
approximately one inch thick in the middle of the
cylinder.
The cell is set up in the following manner.
The waste water, the glass jar, and the porous cup,
to remove first in other instances, the carbon oil-
lar is placed in the glass containing jar. The glass
the for draining off the water solution is inserted
in the right of the glass jar, then the remaining
space between the carbon cylinder and the glass jar
is filled with a material which has a permeability
also of 3.5 inches, with a permeability of about 1-
7 inches is desired, the same is to be used in the
same having a size of about 7.75 inches is desired.
One pound of potassium chloride is then placed on top
of the granular material.
The total weight of the glass jar, the porous cup,
the of the carbon cylinder, and the porous cup is about
17.75 pounds total. The same is to be used in the
cylinder and the glass jar is to be used.
In order to make the test more accurate,
it is as possible to get the same in the

ordinary tap water was used in making the electrolyte. To a known quantity of water was added chemically pure sulphuric acid having a specific gravity of 1.84 until a density of 15° Baumé or 1.115 specific gravity at a temperature of 70° Fahrenheit is secured. A portion of this electrolyte is then poured into the porous cup until about .5 inches from the top and the weight of this inner solution is determined by subtracting that left in the containing jar from the original weight. Additional electrolyte is then poured into the cavity around the carbon element, until it is about .5 inches from the top of the edge of glass. The weight of this outer solution is determined as before. The weight of the electrolyte used in each cell was thus determined.

The cells were allowed to stand on open circuit for ten hours before commencing tests in order to allow them to reach a normal value. The voltage of the cell on open circuit at a temperature of 70° Fahrenheit or 21.1° Centigrade should be about two volts. The voltage of the cells immediately after assembling was .16 volts and after standing 12 hours the value of the E. M. F. was 1.82 to 1.832 volts.

The reason that the voltage did not reach a higher value was probably partly due to the fact that the temperature was rather low.

The cell may be recharged by syphoning the old solution off and adding a new solution having a density two degrees higher than the original solution in order to compensate for the water left in the receptacle from the previous solution. The syphoning apparatus consists of two lengths of rubber tubing connected by a rubber bulb, one of the free ends of the apparatus is to be placed in the liquid to be syphoned and the other end in the receptacle into which the liquid is to be transferred. The receptacle being below the top of the electrolyte the flow can be started by compressing the bulb, closing the opening below the bulb and allowing the bulb to expand, and the liquid to be forced over into the bulb. When the tube is released the electrolyte will continue to flow until all the liquid is transferred or air enters the upper end of the tube destroying the vacuum.

The reason that the voltage of the cell is not
value was probably partly due to the fact that the
temperature was not 100°.

The cell was also subjected to a constant current

of 100 milliamperes for 10 hours.

At the first of the two experiments the cell was

order to compare the results with the results of the first

one from the previous experiment. The apparatus

was consisted of the battery of rubber tubing con-

necting by a rubber bulb, one of the three ends of the

apparatus is to be placed in the liquid to be examined

and the other end in the reservoir of water. The

liquid is to be transferred. The results of the first

one the top of the electrode in the liquid was stated

to be approximately 0.1 volt. The second experiment was

made by placing the bulb in water, and the other

to be forced over into the liquid. The results of the

second the electrolyte was contained in the liquid

and the liquid is transferred to the other end of the

end of the tube between the two vessels.

WEIGHTS OF MATERIALS.

KNIGHTS OF MATERIALS. PLAINTEXT

Weights of Component Parts of Cell Number One.

Glass jar,	6.798	Lbs.
Zinc,	4.05875	"
Porous cup, #53S,	1.773	"
Carbon terminal,	6.383	"
Gass syphoning tube,	.0743	"
Grannular carbon,	3.582	"
Mercury,	2.	"
Potassium chlorate,	1.	"
Contact rod to zinc terminal	.219	"
Outer solution,	6.355	"
Solution in porous cup,	3.847	"
<hr/>		
Total weight,	36.09005	"
Weight of zinc plus mercury		
after test,	5.688	"

after test, 5.688
Weight of zinc plus mercury

Total weight, 36.09005

Solution in porous cup, 3.847

Outer solution, 6.355

Contact rod to zinc terminal .219

Potassium chlorate, .1

Mercury, 2

Granular carbon, 3.582

Gas absorbing tube, .0743

Carbon terminal, 6.383

Porous cup, #532, 1.773

Zinc, 4.05875

Glass jar, 6.798 lbs.

Weights of Component Parts of Cell Number One.

Weights of Component Parts of Cell Number Two.

Glass jar,	6.907	Lbs.
Zinc,	4.0625	"
Porous cup,	1.626	"
Carbon terminal,	6.477	"
Glass syphoning tube,	.0743	"
Grannular carbon,	4.1543	"
Mercury,	2.	"
Potassium chlorate,	1.	"
Contact rod to zinc terminal,	.219	"
Outer solution,	7.237	"
Solution in porous cup,	3.106	"
<hr/>		
Total weight,	36.8631	"

Weight of zinc plus mercury

after test,	5.663	"
-------------	-------	---

Weights of Component Parts of Cell Number Two.

Glass jar,	6.907 lbs.
Zinc,	2.0625
Porous cup,	1.626
Carbon terminal,	6.477
Glass siphoning tube,	0.0743
Granular carbon,	4.1543
Mercury,	3.
Potassium chloride,	1.
Contact rod to zinc terminal,	2.212
Outer solution,	7.237
Solution in porous cup,	3.106
Total weight,	36.8631
Weight of zinc plus mercury after test,	2.663

Weights of Component Parts of Cell Number Three.

Glass jar,	6.682	Lbs.
Zinc,	4.0625	"
Porous cup. S50,	1.860	"
Carbon terminal,	6.688	"
Glass syphoning tube,	.0743	"
Grannular carbon,	3.893	"
Mercury,	2.	"
Potassium chlorate,	1.	"
Contact rod to zinc terminal,	.219	"
Outer solution,	6.739	"
Solution in porous cup,	3.536	"
Total weight,	<u>36.6538</u>	"
Weight of zinc plus mercury after test,	5.663	"

Weights of Component Parts of Cell Number Three.

Glass jar,	6.682 lbs.
Zinc,	4.0632
Porous cup, 250,	1.850
Carbon terminal,	6.688
Glass siphoning tube,	.0748
Granular carbon,	2.893
Mercury,	2.
Potassium chloride,	1.
Contact rod to zinc terminal,	.212
Outer solution,	2.739
Solution in porous cup,	2.552
Total weight,	<hr/> 36.6538

Weight of zinc plus mercury

after test, 5.663

Weights of Component Parts of Cell Number Four.

Glass jar,	3.356	Lbs.
Zinc terminal,	3.992	"
Copper terminal,	.1211	"
Copper sulphate,	1.5	"
Weight of water,	7.265	"
	<hr/>	
Total weight,	16.2341	"
Weight of zinc after test	2.52	"

Weights of Component Parts of Cell Number Four.

3.755 lbs.	Glass jar.
" 3.003	Iron terminal.
" .1211	Copper terminal.
" 1.5	Copper sulphate.
" 7.255	Weight of water.
<hr/>	
" 16.241	Total weight.
" 2.55	Weight of zinc after test

P A R T I.

T E S T NO. I.

DISCHARGING AT A CONSTANT RATE.

DISCHARGING AT A CONSTANT RATE.
TEST NO. I.
PART I.

F I G U R E I.

A SCHEME OF THE CONNECTIONS USED
IN MAKING THE TESTS.

E T G U R E I .

CEBU EXHIBITIONED ARE TO BE USED

IN MAKING THE TESTS.

T E S T N O . 1 .

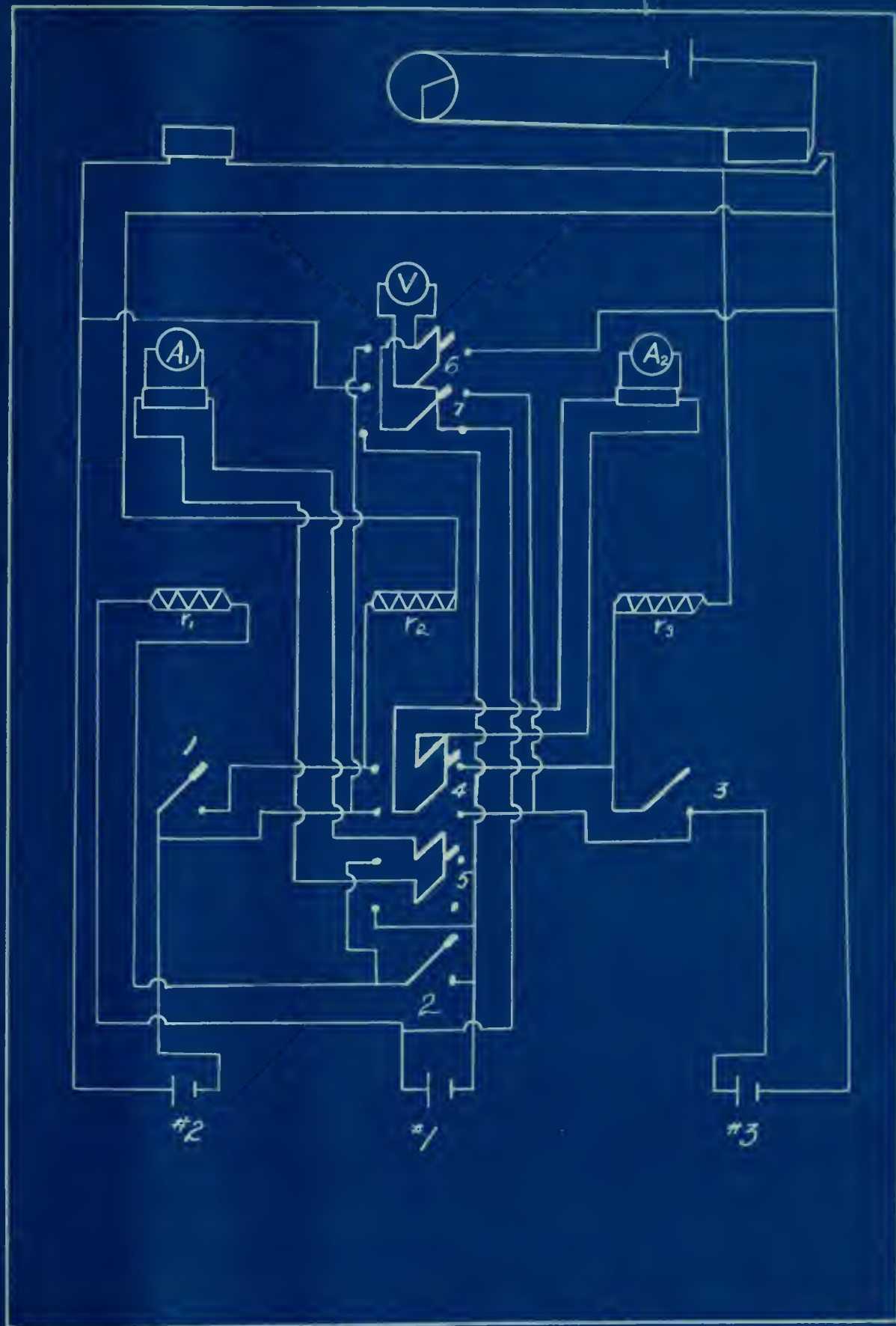
The apparatus used in performing the tests, other than the batteries, consisted of the following:

- (1) 0-3 Direct current, direct reading Weston volt meter.
- (2) 0-100 Milli-volt meter and ampere shunts for 1 and 10 amperes.
- (3) Coil resistances and wire.
- (4) 3 Double pole, double throw switches.
- (5) 3 Single pole, single throw switches.
- (6) 1 Three pole double throw switch.
- (7) 6 Volt storage battery.
- (8) Clock with second-hand attachment.
- (9) 2 Auxiliary relay coils.
- (10) 1 Contact counter.

TEST NO. 1.

The apparatus used in performing the tests, other than the batteries, consisted of the following:

- (1) 0-3 Direct current, direct reading Weston volt meter.
- (2) 0-100 Milli-volt meter and ampere shunts for 1 and 10 amperes.
- (3) Coil resistances and wire.
- (4) 3 Double pole, double throw switches.
- (5) 3 Single pole, single throw switches.
- (6) 1 Three pole double throw switch.
- (7) 6 Volt storage battery.
- (8) Clock with second-hand attachment.
- (9) 2 Auxiliary relay coils.
- (10) 1 Contact counter.



The apparatus was connected according to the scheme shown in Figure 1. Battery #1 was connected in series with switch #2, and resistance r_1 , now by throwing switch #7 to the left, the closed circuit voltage may be read on voltmeter V, and by opening switch #2 the open circuit voltage may be read. The current of cell #1 was determined by throwing switch #5 to the left and opening switch #2.

Cell #2 was connected with a counting relay, auxiliary relay contact, switch #1, and resistance r_2 in series. By throwing switch #4 to the left and opening switch #1, the current may be read on ammeter A_2 . The voltage can be read by throwing switch #6 to the left.

Cell #3 was connected through a switch #3, resistance r_3 and an auxiliary relay (contact). The current was determined by throwing switch #4 to the right and opening switch #3. The voltage being read by throwing switch #6 to the right.

Readings of battery #4 were determined by inserting the ammeter shunt A_1 in the circuit, and connecting the Voltmeter across the terminals.

On the data sheets "I" is the current in amperes; E_1 is the closed circuit voltage; E_2 is the open circuit voltage; D is the density in degrees Baume; and "r" is the resistance of the cell.

The apparatus was connected according to the sch-

emo shown in Figure 1. Battery #1 was connected in series with switch #3, and resistance r_3 , now by throwing switch #7 to the left, the closed circuit voltage may be read on voltmeter V, and by opening switch #3 the open circuit voltage may be read. The current of cell #1 was determined by throwing switch #5 to the left and opening switch #2.

Cell #2 was connected with a counting relay, auxiliary relay contact, switch #1, and resistance r_2 in series. By throwing switch #4 to the left and opening switch #1, the current may be read on ammeter A. The voltage can be read by throwing switch #6 to the left.

Cell #3 was connected through a switch #3, resistance r_3 , and an auxiliary relay contact. The current was determined by throwing switch #4 to the right and opening switch #5. The voltage being read by throwing switch #6 to the right.

Readings of battery #4 were determined by in-

serting the ammeter about A₁ in the circuit, and connecting the voltmeter across the terminals.

On the data sheets "I" is the current in amperes:

E_1 is the closed circuit voltage; E_2 is the open circuit voltage; D is the density in farads per square centimeter; and "r" is the resistance of the cell.

The value of "r" is determined from the known values of E_1 , E_2 , and I by use of the formula,

$$r = \frac{E_2 - E_1}{I}$$

The temperature, density, current, open and closed circuit voltage was determined every eight hours for a period of 560 hours. In test # 1, the cell was discharged through a fixed resistance at an average rate of .2097 amperes. The average potential applied being 1.554 volts. The circuit was disturbed but momentarily when the readings were taken.

Curves for each of the cells tested were plotted showing the relation between amperes, volts, temperature and time in hours. Care was used in plotting the curves, they being secured by plotting from point to point and the average value of the ordinates determined by the use of a planimeter.

Calculations and Results.

It will be noticed from a consideration of the data, that the resistance of cell # 1 increased from .1571 to .246 ohms, and that the value was affected slightly by temperature.

Knowing the average voltage and current per cell, the watts output may be calculated from the formula:

$$W = E_1 I$$

The value of "r" is determined from the known

values of E_1 , E_2 , and I by use of the formula,

$$r = \frac{E_2 - E_1}{I}$$

The temperature, density, current, open and closed

circuit voltage was determined every eight hours

for a period of 280 hours. In test #1, the cell was

discharged through a fixed resistance at an average

rate of .2087 amperes. The average potential applied

being 1.524 volts. The circuit was disturbed but

momentarily when the readings were taken.

Curves for each of the cells tested were plotted

showing the relation between amperes, volts, temperature

and time in hours. Care was used in plotting the y

curves, they being secured by plotting from point to

point and the average value of the ordinates determined

by the use of a planimeter.

Calculations and Results.

It will be noticed from a consideration of the

data, that the resistance of cell #1 increased from

.1571 to .346 ohms, and that the value was affected

slightly by temperature.

Knowing the average voltage and current per cell,

the watts output may be calculated from the formula:

$$W = E_1 I$$

and knowing the total number of hours the cells were discharged, the total watt-hours per cell may be determined by the use of the formula:

$$W^1 = E I t$$

in which W^1 equals output in watt-hours, and t is total time in hours.

Both the inner and outer solutions, in this test had a density of 15⁰ Baume at 70⁰ Fahrenheit.

weight of zinc+ Hg before test = 6.05875

weight of zinc+ Hg after test = 5.707

weight of zinc consumed = .35175# or 160 grams.

The area of the ampere-hour curve = 29.22 sq. in.
 1 sq. in. = 4 ampere-hours giving 116.88 ampere-hours
 giving an average I of .2097 or ampere-hours output =
 .2097 x 560 = 116.88.

Theoretical loss = 116.88 x 3600 x .000336 =
 141.5 grammes of zinc, in which 3600 is a conversion
 factor for changing ampere-hours into coulombs, namely
 amperes per second, and .000336 is the electro-chemical
 equivalent of zinc.

Therefore 18.5 grammes are consumed by local action
 and the efficiency is $141.5 \div 160$ or 88.5 %.

and knowing the total number of hours the cells were discharged, the total watt-hours per cell may be determined by the use of the formula:

$$W = E I t$$

in which W equals output in watt-hours, and t is total time in hours.

Both the inner and outer solutions, in this test

had a density of 1.5 Baume at 70° Fahrenheit.

weight of zinc before test = 6.05875

weight of zinc after test = 5.707

weight of zinc consumed = .35175 or 160 grams.

The area of the ampere-hour curve = 22.88 ad. in.

ad. in. = 4 ampere-hours giving 116.88 ampere-hours

giving an average I of .3097 or ampere-hours output =

$$.3097 \times 360 = 111.68.$$

$$\text{Theoretical loss} = 116.88 \times 3600 \times .000336 =$$

141.5 grams of zinc, in which 3600 is a conversion

factor for changing ampere-hours into coulombs, namely

amperes per second, and .000336 is the electro-chemical

equivalent of zinc.

Therefore 141.5 grams are consumed by local action

and the efficiency is $141.5 \div 160$ or 88.5 %.

Cost of Materials

Cell # 1.

Weight of outer solution = 6.355 lbs.

Weight of cup solution = 3.847 lbs.

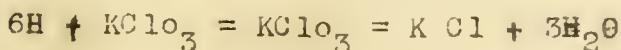
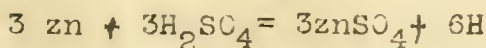
Total weight of solution = 10.202 lbs.

Since density of acid = 15° Baume = 1.116 sp. gr.
wt. of 1.116 sp. gr. solution per cu. ft. = 69.6022,
per cent of acid in 1.116 sp. gr. solution = 15.904,
therefore weight of actual acid in solution = 10.202
lbs. x .15904 = 1.61 lbs.

As the cells were not completely exhausted, the
chemical equivalent of material used would be as
follows: H_2SO_4 consumed equals atomic wt. of H_2SO_4
 $\div \frac{97.92}{64.82} = 1.509.$

The actual consumption of 100% acid equals
 $1.509 \times .35175 \text{ lbs. zn.} = .565 \text{ lbs. of acid.}$
The commercial acid consumed equals $.565 \div .96$
 $= .589 \text{ lbs. commercial acid consumed.}$ Then at
1.5 cents per pound, the acid used would cost .884 Cents

The K ClO_3 consumed would be determined as follows:
since one molecule of K ClO_3 combines with six molecules
of H and as,



Cost of Materials

Cell # 1.

Weight of outer solution = 6.322 lbs.
Weight of cup solution = 3.847 lbs.
Total weight of solution = 10.202 lbs.

Since density of acid = 1.16 gms. per cu. cm.
wt. of 1.16 sp. gr. solution per cu. cm. = 1.16 gms.
per cent of acid in 1.16 sp. gr. solution = 15.904
therefore weight of actual acid in solution = 10.202

lbs. x .15904 = 1.621 lbs.

As the cells were not completely exhausted, the

chemical equivalent of material used would be an

Follows: H_2SO_4 consumed equals atomic wt. of H_2SO_4

$$\frac{.64.88}{.97.92} = 1.509.$$

The actual consumption of 100% acid equals

1.509 x .35175 lbs. cu. = .529 lbs. of acid.

The commercial acid consumed equals .529 ÷ .98

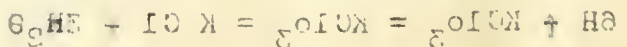
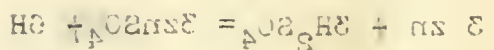
= .539 lbs. commercial acid consumed. Then at

1.5 cents per pound, the acid used would cost .8084 cents

The $KClO_3$ consumed would be determined as follows:

since one molecule of $KClO_3$ combines with six molecules

of H and as



therefore atomic weight of $\text{K ClO}_3 \div$ atomic wt. of H_2SO_4 will equal amount of K ClO_3 required or, $122.28 \div 293.76 = .418$ times actual acid used, or $.418 \times .589 = .246$ lbs. K ClO_3 , and since K ClO_3 costs 9.5 cents per pound, the amount consumed would cost 2.318 cents.

Zinc consumed = .35175 lbs. and costs at 8.5 cents per pound, 3 cents.

The total cost of the material used in the cell when the average voltage of cell was 1.554 volts, and the average current was .209 amperes for 560 hrs. giving 181.2 watt-hours, was as follows: assuming the available chemical efficiency as 80% for the H_2SO_4 and K ClO_3 would be 7.02 cents.

The cost per K.W. hr. output would be 38.7 cts. The foregoing cost shows the possible minimum of commercial cost per K.W.hr. based upon a chemical efficiency of 80% which seems to have been obtained on complete discharge tests.

therefore atomic weight of $KClO_3 =$ atomic wt. of H_2SO_4
 will equal amount of $KClO_3$ required or, $122.28 \div 98.08 =$
 $= .418$ times actual acid used, or $.418 \times .589 = .246$ lbs
 $KClO_3$, and since $KClO_3$ costs 2.5 cents per pound, the
 amount consumed would cost 2.318 cents.
 Zinc consumed = .35175 lbs. and costs at 8.5 cents p
 per pound, 3 cents.
 The total cost of the material used in the cell
 when the average voltage of cell was 1.554 volts,
 and the average current was .209 amperes for 560 hrs.
 giving 181.3 watt-hours, was as follows: assuming
 the available chemical efficiency as 80% for the
 H_2SO_4 and $KClO_3$ would be 7.02 cents.
 The cost per K.W. hr. output would be 38.7 cts.
 The foregoing cost shows the possible minimum of com-
 mercial cost per K.W. hr. based upon a chemical eff-
 iciency of 80% which seems to have been obtained on
 complete discharge tests.

C E L L N O . I .

Time	E 1	E 2	I	Density	r.	Hrs.
2 AM		.16	0	15		
2 PM		1.832		16.0		
10	1.723	1.766	.21	16.2	.1571	8
6 AM	1.70	1.734	.22	16.4	.1545	16
2 PM	1.73	1.765	.225	16.5	.1555	24
10	1.74	1.776	.21	16.45	.171	32
6 AM	1.66	1.706	.215	16.8	.168	40
2	1.63	1.666	.21	16.9	.171	48
10	1.594	1.63	.199	17.	.181	56
6 AM	1.587	1.620	.20	17.1	.180	64
2 PM	1.58	1.618	.205	17.4	.186	72
	6 oz. H ₂ O added					
10	1.594	1.63	.21	15.9	.171	80
6 AM	1.574	1.61	.203	16.5	.177	88
2 PM	1.572	1.61	.203	17.5	.187	96
10	1.656	1.695	.215	17.4	.181	104
6 AM	1.547	1.586	.215	17.4	.183	112
2 PM	1.555	1.596	.2151	17.5	.199	120
10	1.536	1.576	.205	18.	.197	128
6 AM	1.600	1.639	.209	17.8	.186	136
	6 oz. H ₂ O added					

Time	E I	E S	I	Depart- ure	r.	Hrs.
8 AM		1.16	0	12		
8 PM		1.832		12.0		
10	1.732	1.766	21	16.3	1.751	8
6 AM	1.70	1.734	22	16.4	1.745	16
8 PM	1.73	1.762	222	16.5	1.752	24
10	1.74	1.776	21	16.45	1.71	32
6 AM	1.66	1.706	215	16.8	1.76	40
8	1.63	1.666	21	16.9	1.71	48
10	1.634	1.63	192	17	1.61	56
6 PM	1.627	1.650	20	17.1	1.60	64
8 PM	1.52	1.618	202	17.4	1.56	72
6 02. 150 added						
10	1.574	1.63	21	17.5	1.71	80
6 AM	1.574	1.61	202	16.5	1.77	88
8 PM	1.572	1.61	202	17.5	1.67	96
10	1.556	1.632	215	17.4	1.61	104
6 AM	1.547	1.586	215	17.4	1.62	112
8 PM	1.525	1.596	2151	17.5	1.62	120
10	1.522	1.576	202	18	1.57	128
6 AM	1.600	1.632	202	17.5	1.66	136
6 02. 150 added						

C E L L N O . L .

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 PM	1.62	1.658	.22	15.	.175	144
10	1.598	1.646	.22	16.	.177	152
6 AM	1.566	1.606	.21	17.7	.190	160
2 PM	1.57	1.61	.212	17.7	.188	168
10	1.576	1.616	.212	17.7	.194	176
6 AM	1.576	1.617	.22	17.5	.186	184
2 PM	1.581	1.618	.219	17.	.169	192
10	1.584	1.626	.216	17.5	.194	200
6 AM	1.605	1.646	.219	18.	.187	208
	6 oz. H ₂ O added					
2 PM	1.588	1.628	.218	16.3	.185	216
10	1.585	1.626	.218	16.3	.186	224
6 AM	1.585	1.626	.212	17.2	.196	232
2 PM	1.582	1.623	.213	17.2	.195	240
10	1.569	1.61	.208	17.5	.197	248
6 AM	1.51	1.551	.208	18.	.197	256
2 PM	1.534	1.575	.21	19.	.195	264
10	1.535	1.576	.211	19.1	.194	272
6 AM	1.524	1.565	.21	19.5	.197	280

Time	Lat	Long	Alt	Dist	Time	Lat	Long	Alt	Dist
144	175	15	35	1.538	154	175	15	35	1.538
155	177	16	35	1.540	165	177	16	35	1.540
160	180	17.7	37	1.506	170	180	17.7	37	1.506
168	188	17.7	37.5	1.51	178	188	17.7	37.5	1.51
176	194	17.7	37.5	1.515	186	194	17.7	37.5	1.515
184	186	17.5	38	1.517	194	186	17.5	38	1.517
195	193	17	37.5	1.518	205	193	17	37.5	1.518
200	194	17.5	37.5	1.526	210	194	17.5	37.5	1.526
208	187	18	37.5	1.546	218	187	18	37.5	1.546
216	185	16.3	37.5	1.538	226	185	16.3	37.5	1.538
234	186	16.3	37.5	1.536	244	186	16.3	37.5	1.536
238	186	17.5	37.5	1.536	248	186	17.5	37.5	1.536
240	185	17.5	37.5	1.533	250	185	17.5	37.5	1.533
248	197	17.5	38	1.51	256	197	17.5	38	1.51
256	197	18	38	1.531	264	197	18	38	1.531
264	195	19	37	1.525	272	195	19	37	1.525
275	194	19.1	37.1	1.525	280	194	19.1	37.1	1.525
280	197	19.5	37	1.525					

C E L L NO. I.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 PM	1.541	1.583	.213	20.	.209	288
10	1.54	1.582	.213	20.	.208	296
6 AM	1.524	1.566	.2	20.1	.21	304
2 PM	1.534	1.576	.2	20.2	.21	312
10	1.525	1.57	.21	20.8	.208	320
6 AM	1.518	1.56	.2	20.9	.21	328
	6 oz. H ₂ O added					
2 PM	1.557	1.570	.208		.207	336
10	1.52	1.563	.202	21.7	.213	344
6 AM	1.526	1.569	.203	21.	.216	352
2 PM	1.534	1.577	.208	20.7	.207	360
10	1.527	1.57	.208	21.	.207	368
6 AM	1.517	1.569	.212	21.5	.203	376
2 PM	1.516	1.558	.208	22.	.202	384
10	1.518	1.56	.203	22.1	.207	392
6 AM	1.503	1.546	.209	22.5	.206	400
2 PM	1.502	1.546	.209	22.5	.211	408
10	1.514	1.558	.21	22.8	.209	416
6 AM	1.486	1.53	.208	22.9	.216	424
2 PM	1.53	1.566	.208	23.	.208	432

Time	H I	H S	I	Dens- ty	r	Prs.
2 PM	1.541	1.583	.213	.20.	.203	388
10	1.54	1.583	.213	.20.	.208	396
6 AM	1.534	1.566	.2	.20.1	.21	304
2 PM	1.534	1.576	.2	.20.2	.21	312
10	1.535	1.57	.21	.20.8	.208	320
6 AM	1.518	1.56	.2	.20.9	.21	328
	6.02. H80 sqdqd					
2 PM	1.527	1.570	.208		.207	336
10	1.52	1.563	.203	.21.7	.213	344
6 AM	1.526	1.569	.203	.21.	.216	352
2 PM	1.534	1.577	.208	.20.7	.207	360
10	1.527	1.57	.208	.21.	.207	368
6 AM	1.517	1.569	.212	.21.5	.203	376
2 PM	1.516	1.558	.208	.22.	.203	384
10	1.518	1.56	.203	.22.1	.207	392
6 AM	1.503	1.546	.203	.22.2	.206	400
2 PM	1.502	1.545	.203	.22.3	.211	408
10	1.514	1.558	.21	.22.8	.209	416
6 AM	1.486	1.53	.208	.22.9	.216	424
2 PM	1.52	1.566	.208	.23.	.208	432

C E L L N O . I .

Time	E 1	E 2	I	Densi- ty	r	Hrs
10 PM	1.52	1.566	.209	23.	.206	440
6 AM	1.524	1.558	.211	23.5	.208	448
2 PM	1.511	1.556	.21	24.	.214	456
10 PM	1.505	1.545	.21	23.9	.214	464
6 AM	1.515	1.560	.209	24.1	.215	472
2 PM	1.486	1.532	.213	24.	.216	480
	6 oz. H ₂ O added					
10	1.476	1.523	.21	22.5	.222	488
6 AM	1.52	1.566	.212	22.8	.217	496
2 PM	1.52	1.566	.21	23.1	.219	504
10	1.524	1.57	.21	23.2	.219	512
6 AM	1.490	1.536	.211	24.	.218	520
2 PM	1.50	1.546	.218	24.2	.224	528
10 PM	1.476	1.52	.2	24.5	.21	536
6 AM	1.51	1.557	.205	24.1	.229	544
2 PM	1.52	1.57	.203	24.8	.246	552
10 P.M.	1.47	1.52	.205	25.	.24	560

Time	E 1	E 2	I	Depth - ft	T	Lat
10 AM	1.52	1.566	309	33.	309.	410
9 AM	1.524	1.552	311	33.2	308.	418
8 PM	1.511	1.533	31	34.	314.	402
10 PM	1.505	1.545	31	33.3	304.	404
6 AM	1.513	1.530	309	34.1	313.	417
8 PM	1.489	1.532	313	34.	310.	409
	6 02. H ₂ O 89499					
10	1.476	1.523	31	33.8	309.	488
9 AM	1.52	1.569	313	33.8	317.	466
8 PM	1.52	1.566	31	33.1	319.	504
10	1.524	1.57	31	33.3	319.	503
6 PM	1.493	1.539	311	34.	313.	510
8 PM	1.50	1.546	318	34.3	334.	523
10 PM	1.476	1.52	3.	34.6	33.	539
6 AM	1.51	1.577	309	34.1	333.	544
8 PM	1.52	1.57	303	34.3	345.	573
10 PM	1.47	1.52	305	35.	34.	569

VOLTAGE-TIME CURVE TEST '1 CELL '1

1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

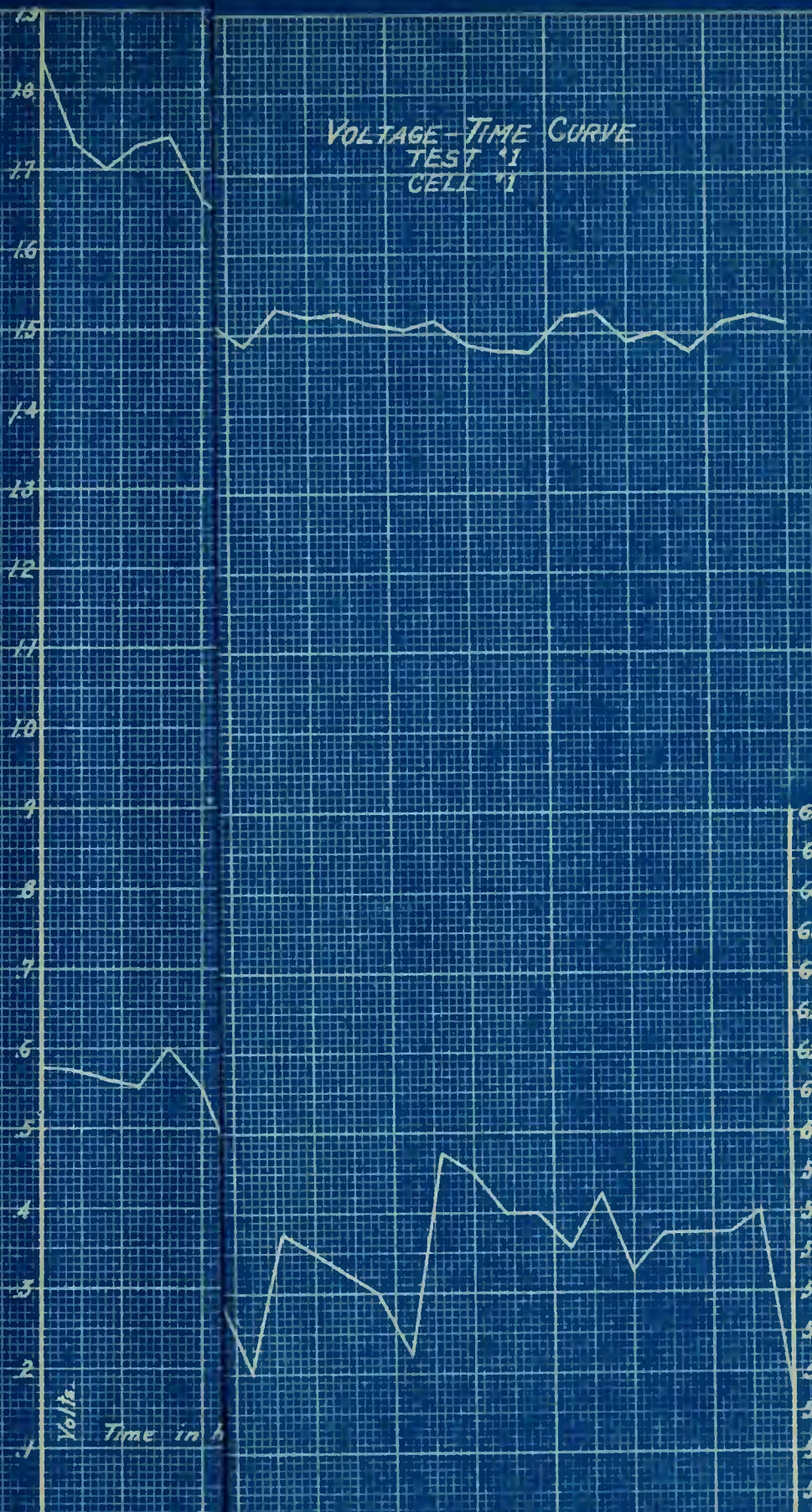
Volts

Time in h

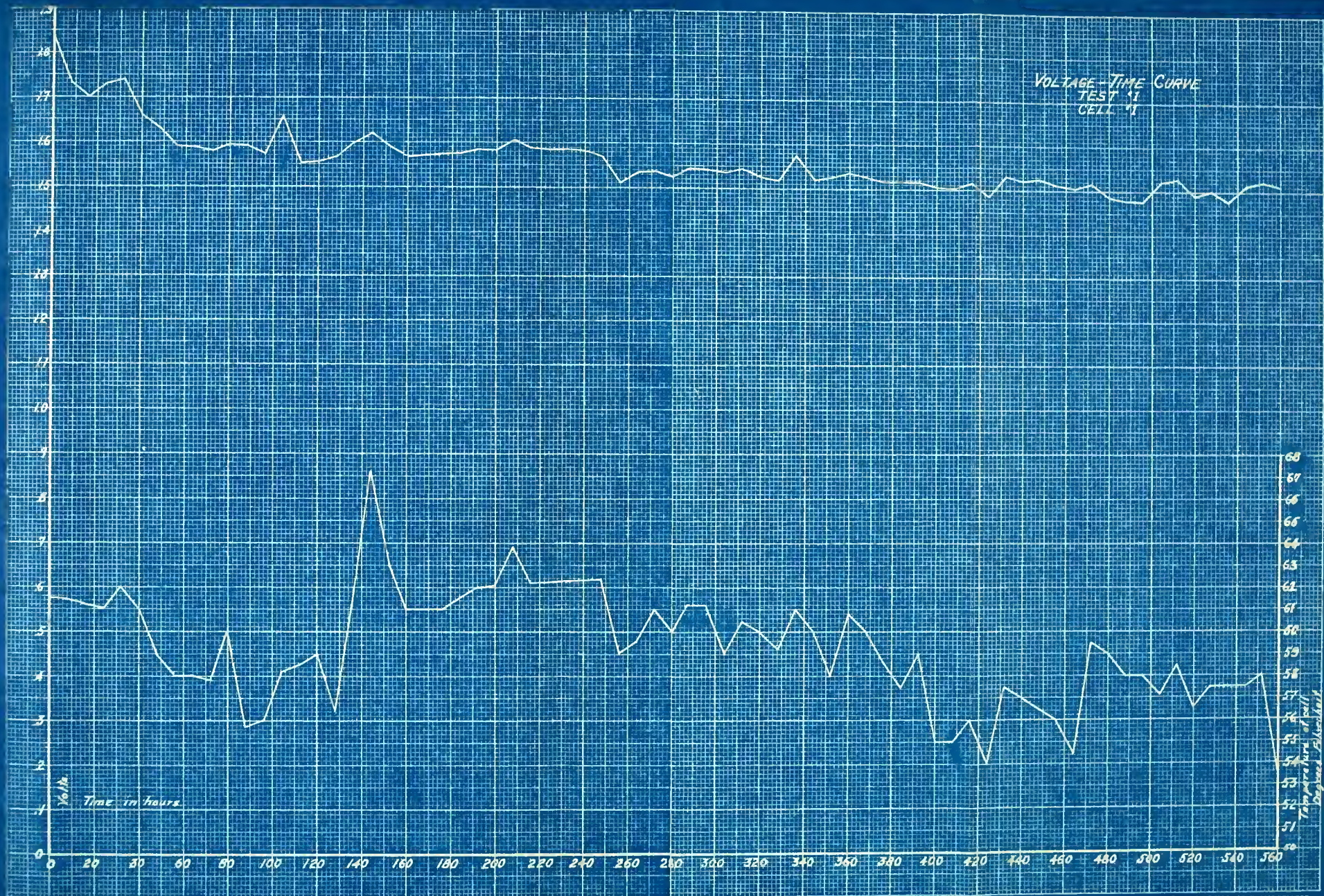
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50

Temperature of cell
Degrees Fahrenheit

0 20 30 320 340 360 380 400 420 440 460 480 500 520 540 560



Time	E I	E S	I	Dust- ty	r	W
10 PM	1.52	1.52	1.52	23.	23.	440
8 PM	1.524	1.522	1.521	23.2	23.2	418
2 PM	1.511	1.523	1.51	24.	24.	422
10 PM	1.505	1.545	1.51	23.2	23.2	404
8 PM	1.512	1.520	1.509	24.1	24.1	471
2 PM	1.482	1.522	1.512	24.	24.	427
H ₂ O 84499						
10	1.476	1.523	1.51	23.2	23.2	488
8 PM	1.52	1.522	1.512	23.2	23.2	462
2 PM	1.52	1.522	1.51	23.1	23.1	404
10	1.524	1.51	1.51	23.2	23.2	512
8 PM	1.491	1.522	1.511	24.	24.	680
2 PM	1.50	1.545	1.518	24.2	24.2	522
10 PM	1.476	1.52	1.51	24.2	24.2	522
8 PM	1.51	1.527	1.505	24.1	24.1	544
2 PM	1.52	1.52	1.508	24.2	24.2	522
10 PM	1.47	1.52	1.505	22.	22.	500



AVERAGE TIME CURVE

TEST #1

DATE 11/1

Amplitude

Time in hrs

0

20

40

60

80

100

120

140

160

180

200

220

240

260



AVERAGE TIME CURVE
(LEFT
CHANNEL)

Amplitude
Time in hours

0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820 840 860 880 900 920 940 960 980 1000

Test # 1.

Test # 2.

In this test the cell was operated at a constant current of 1.5 amperes during the discharge. The cell was continuously discharged for a period of 15.5 seconds and during this time the voltage dropped to a minimum value of 2.85 volts.

THE RESULTS OF PART II OF THE TEST FOR THIS CELL ARE SHOWN IN Test # 2, set # 1.

DISCHARGING AT AN INTERMITTANT RATE.

Weight of cell at start of test = 1.0000 lbs.
Weight of cell at end of test = 1.0000 lbs.
Weight of air consumed = 0.0000 lbs. - 1.0000 lbs.

In 150 hours there were 150 x 10 = 1500 minutes of 15.5 seconds each at 1.5 amperes or equivalent to 4500.00 = 1500 x 3000 x .0030 = 1350.00 lbs.

During this period the variation of current was small and the variation of the cell voltage was small. The current being discharged is plotted from 1000 to 1500. The shape of the current-time curve, and voltage-time curve were determined accurately by the use of a planimeter, and the average value of the current and voltage were determined.

The following table shows the results of this test.

1947

1948

DISCHARGING AT AN INTERMEDIATE RATE.

Test # 2.

Cell # 2.

In this test the cell was prepared the same as in Test #1 using a solution having the same density. The cell was automatically discharged for a period of 10.5 seconds once during each two minutes through a resistance giving an average value of current of 2.88 amperes.

The quantities on the data sheets for this test have the same meaning as in Test # 1.

Calculations and Results.

Weight of Zn + H₂ before test = 6.0586 lbs.

Weight of Zn + H₂ after test = 5.642 lbs.

Weight of Zn consumed = .4166 lbs. = 188 gms.

In 560 hours there were 560×30 or 16800 contacts of 10.5 seconds each at 2.88 amperes or equivalent to $49 \times 2.88 = 141.2 \times 3600 \times .000336 = 171.1$ gms.

Curves were plotted showing the variation of amperes volts and temperature of the cell with time in hours. The curves being determined by plotting from point to point. The areas of the ampere-time curve, and volt-time curve were determined accurately by the use of a planimeter, and the average value of the current and voltage were determined therefrom.

The zinc consumed by local action in this cell

Test # 2.

Cell # 2.

In this test the cell was prepared the same as in

Test #1 using a solution having the same density. The cell was automatically discharged for a period of 10.5 seconds once during each two minutes through a resistance giving an average value of current of 2.88 amperes.

The quantities on the data sheets for this test

have the same meaning as in Test # 1.

Calculations and Results.

Weight of Zn before test = 6.0586 lbs.
Weight of Zn after test = 5.642 lbs.
Weight of Zn consumed = .4166 lbs. = 188 gms.

In 560 hours there were 560 x 30 or 16800 contacts of 10.5 seconds each at 2.88 amperes or equivalent to $49 \times 2.88 = 141.2 \times 3600 \times .000532 = 171.1$ gms.

Curves were plotted showing the variation of amperes, volts and temperature of the cell with time in hours. The curves being determined by plotting from point to point. The areas of the amper-time curve, and volt-time curve were determined accurately by the use of a planimeter, and the average value of the current and voltage were determined therefrom.

The zinc consumed by local action in this cell

was 16.9 gms., therefore the efficiency was 91.25%

Cost of Materials.

Weight of outer solution = 7.237 lbs.

Weight of inner solution = 3.106 lbs.

Total weight of solution = 10.443 lbs.

Since the density of acid = 15° Baum, or 1.116 lbs sp. gr., a cu. ft. of this liquid weighs 69.6022 lbs, and contains 15.904% acid, the weight of acid in liquid is 1.67 lbs.

H_2SO_4 consumed = 1.509 x .4166 lbs. = .629 lbs. 100% acid or .655 lbs. commercial acid, which would cost .987 cents. The K ClO_3 consumed equals .418 x .655 = .272 lbs., or zinc consumed would cost 3.549 cents.

The total cost of materials consumed allowing 80% chemical efficiency for H_2SO_4 and K ClO_3 , in producing 186 watts is 7.689 cents or 43.1 cents per K.W. hour.

was 16.9 gms., therefore the solution was 31.25%

Cost of Materials.

Weight of outer solution = 7.337 lbs.

Weight of inner solution = 3.106 lbs.

Total weight of solution = 10.443 lbs.

Since the density of acid = 1.848, or 1.16 lbs

sp. gr., a cu. ft. of this liquid weighs 69.608 lbs,

and contains 15.904% acid, the weight of acid in

liquid is 1.67 lbs.

H_2SO_4 consumed = $1.509 \times .416$ lbs. = .628 lbs.

100% acid or .655 lbs. commercial acid, which would

cost .387 cents. The $KClO_3$ consumed equals $.416 \times$

.655 = .272 lbs., or zinc consumed would cost

3.549 cents.

The total cost of materials consumed allowing 80%

chemical efficiency for H_2SO_4 and $KClO_3$, in producing

166 watts is 7.689 cents or 43.1 cents per "W." hour.

C E L L NO. II.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 AM		.16		15.		
12:30 PM		1.821		16.5		
10	1.46	1.761	2.81	17.	.106	8
6 AM	1.44	1.76	2.85	17.	.109	16
2 PM	1.506	1.81	2.81	17.	.109	24
10 PM	1.46	1.76	2.9	17.	.105	32
6 AM	1.426	1.761	3.11	17.	.107	40
	14.5 oz. H ₂ O added					
2 PM	1.377	1.717	3.11	15.	.1094	48
10	1.387	1.717	3.1	16.1	.105	56
6 AM	1.38	1.711	3.06	16.2	.107	64
2 PM	1.356	1.678	3.05	16.8	.1058	72
10	1.36	1.666	3.06	16.5	.100	80
6 AM	1.33	1.64	3.09	16.8	.100	88
2 PM	1.338	1.638	2.99	17.	.1008	96
10	1.336	1.64	2.995	17.5	.103	104
6 AM	1.35	1.674	3.01	17.5	.1075	112
2 PM	1.34	1.65	3.02	17.4	.102	120

CHILLI

Time	1	2	3	4	5	6
3 AM			1.36			
12:30 PM			1.37			
10	1.46	1.76	1.76	1.76	1.76	1.76
6 AM	1.44	1.76	1.76	1.76	1.76	1.76
3 PM	1.50	1.81	1.81	1.81	1.81	1.81
10 PM	1.46	1.76	1.76	1.76	1.76	1.76
6 AM	1.48	1.77	1.77	1.77	1.77	1.77
	14.5	14.5	14.5	14.5	14.5	14.5
3 PM	1.37	1.77	1.77	1.77	1.77	1.77
10	1.38	1.77	1.77	1.77	1.77	1.77
6 AM	1.38	1.77	1.77	1.77	1.77	1.77
3 PM	1.38	1.77	1.77	1.77	1.77	1.77
10	1.38	1.77	1.77	1.77	1.77	1.77
6 AM	1.38	1.77	1.77	1.77	1.77	1.77
3 PM	1.38	1.77	1.77	1.77	1.77	1.77
10	1.38	1.77	1.77	1.77	1.77	1.77
6 AM	1.38	1.77	1.77	1.77	1.77	1.77
3 PM	1.38	1.77	1.77	1.77	1.77	1.77

C E L L NO. II.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
10 PM	1.34	1.65	3.02	18.5	.102	128
6 AM	1.336	1.646	2.93	18.2	.102	136
	3 oz. H ₂ O added					
2 PM	1.326	1.66	2.89	17.5	.1176	144
10	1.317	1.636	2.89	16.5	.109	152
6 AM	1.318	1.618	2.98	17.2	.1006	160
2 PM	1.33	1.636	2.99	17.5	.104	168
10	1.336	1.606	2.86	17.5	.107	176
6 AM	1.33	1.616	2.83	18.	.1008	184
2 PM	1.34	1.62	2.875	17.8	.1004	192
10	1.336	1.616	2.83	18.1	.099	200
6 AM	1.332	1.62	2.87	18.6	.1001	208
	6 oz. H ₂ O added					
2 PM	1.336	1.617	2.9	18.1	.0973	216
10	1.358	1.638	2.81	18.6	.0998	224
6 AM	1.346	1.617	2.82	18.8	.0995	232
2 PM	1.336	1.628	2.89	19.3	.0975	240

C E L I 10. 11.

Time	1	2	3	4	5	6
10 PM	1.84	1.85	3.02	18.2	108	108
9 AM	1.856	1.848	2.82	18.2	108	108
3 PM	1.852	1.86	3.89	17.5	114	114
10	1.817	1.855	2.99	18.2	108	108
6 AM	1.818	1.818	2.98	17.8	100	100
3 PM	1.83	1.856	2.92	17.5	104	104
10	1.836	1.860	2.88	17.5	107	107
6 AM	1.83	1.818	2.83	18.	108	108
3 PM	1.84	1.82	2.875	17.8	104	104
10	1.836	1.818	2.83	18.1	109	109
3 PM	1.832	1.82	2.87	18.2	107	107
3 PM	1.836	1.817	2.9	18.1	107	107
10	1.858	1.858	2.81	18.2	109	109
6 AM	1.846	1.817	2.82	18.8	109	109
3 PM	1.836	1.828	2.99	19.2	108	108

C E L L NO. II.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
10 PM	1.336	1.616	2.91	20.	.0963	248
6 AM	1.296	1.606	2.86	20.	.1085	256
2 PM	1.306	1.611	3.01	21.	.1012	264
10	1.296	1.586	2.91	21.3	.0998	272
6 AM	1.296	1.616	2.81	21.8	.114	280
2 PM	1.316	1.621	2.96	21.9	.1028	288
10 PM	1.311	1.616	2.89	22.	.1055	296
6 AM	1.316	1.62	2.89	22.8	.105	304
2 PM	1.316	1.616	2.94	22.8	.1021	312
10 PM	1.296	1.586	2.89	23.	.1008	320
6 AM	1.3	1.596	2.89	23.5	.1002	328
2 PM	1.296	1.596	2.86	23.	.105	336
	6 oz. H ₂ O added					
10	1.3	1.39	2.87	23.	.101	344
6 AM	1.268	1.55	2.8	23.5	.101	352
2 PM	1.30	1.596	2.84	24.	.104	360
10	1.32	1.596	2.84	24.	.097	368
6 AM	1.3	1.586	2.83	25.	.1011	376

Time	I	Per- cent	T	Rate.	
10 PM	1.386	1.416	2.81	30.	348
9 AM	1.386	1.406	2.82	30.	356
8 PM	1.308	1.411	2.01	21.	364
10	1.308	1.386	2.81	21.3	372
9 AM	1.386	1.416	2.81	21.3	380
8 PM	1.316	1.421	2.82	21.6	388
10 PM	1.311	1.416	2.82	22.	396
9 AM	1.316	1.42	2.82	22.3	404
8 PM	1.316	1.416	2.84	22.6	412
10 PM	1.386	1.386	2.82	22.	420
9 AM	1.3	1.386	2.82	22.3	428
8 PM	1.386	1.386	2.82	22.	436
H. O. 2494					
10	1.3	1.32	2.87	23.	444
9 AM	1.368	1.32	2.8	23.2	452
8 PM	1.30	1.322	2.84	24.	460
10	1.32	1.322	2.34	24.	468
9 AM	1.3	1.322	2.33	25.	476

C E L L NO. II.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 PM	1.28	1.576	2.81	25.	.102	384
10	1.26	1.578	2.56	25.	.118	392
6 AM	1.242	1.576	2.76	25.	.121	400
2 PM	1.262	1.576	2.73	25.1	.1151	408
10	1.25	1.564	2.83	25.5	.111	416
6 AM	1.22	1.558	2.93	26.	.1161	424
2 PM	1.22	1.556	2.89	25.5	.113	432
10	1.24	1.559	2.89	26.	.1102	440
6 AM	1.23	1.566	3.01	26.3	.113	448
2 PM	1.24	1.566	2.74	26.3	.119	456
10 PM	1.25	1.576	2.81	26.4	.116	464
6 AM	1.24	1.566	2.86	27.5	.114	472
2 PM	1.26	1.571	2.8	26.5	.113	480
,	6 oz. H ₂ O added					
10 PM	1.24	1.566	2.7	25.5	.1208	488
6 AM	1.23	1.576	2.71	26.5	.1276	496
2 PM	1.23	1.576	2.81	26.2	.1241	504

Time	I	E	I	Carry	r	Ans.
2 PM	1.28	1.576	2.81	25.	108.	284
10	1.28	1.578	2.58	25.	118.	282
6 AM	1.248	1.576	2.78	25.	121.	400
2 PM	1.282	1.576	2.78	25.1	1181.	402
10	1.28	1.564	2.83	25.2	111.	412
6 AM	1.28	1.558	2.78	25.	1181.	421
2 PM	1.28	1.552	2.92	25.5	118.	422
10	1.24	1.552	2.52	25.	1102.	440
6 AM	1.28	1.562	2.01	25.3	118.	448
2 PM	1.24	1.562	2.74	25.2	118.	432
10 PM	1.28	1.576	2.81	25.4	118.	464
6 AM	1.24	1.562	2.82	25.5	114.	472
2 PM	1.28	1.571	2.8	25.5	118.	482
	6 02.	1.50 added				
10 PM	1.24	1.562	2.7	25.2	1002.	482
6 AM	1.28	1.572	2.71	25.2	1002.	482
2 PM	1.28	1.576	2.81	25.8	1041.	504

C E L L NO. II.

Time	E 1	E 2	I	Dens- ty	r	Hrs.
10 PM	1.21	1.556	2.80	26.5	.1278	512
6 AM	1.21	1.546	2.73	27.1	.123	520
2 PM	1.30	1.637	2.80	27.1	.121	528
10 PM	1.21	1.556	2.71	27.1	.1277	536
6 AM	1.24	1.576	2.7	27.4	.1212	544
2 PM	1.2	1.556	2.76	27.4	.128	552
10	1.2	1.536	2.71	28.1	.124	560

C E L I NO. 11.

Time	W	F	S	I	Penal- ty	r	Hrs.
10 PM	1.21	1.22	1.23	2.80	2.82	1.278	218
6 AM	1.21	1.24	1.25	2.73	2.71	1.282	220
3 PM	1.30	1.23	1.28	2.80	2.71	1.281	223
10 PM	1.21	1.22	1.23	2.71	2.71	1.277	225
6 AM	1.24	1.27	1.27	2.7	2.74	1.218	244
3 PM	1.2	1.22	1.22	2.76	2.74	1.28	245
10	1.2	1.23	1.21	2.71	2.71	1.284	250

VOLTAGE-TIME CURVE TEST #2 CELL #2

1.9

1.8

1.7

1.6

1.5

1.4

1.3

1.2

1.1

1.0

0.9

0.8

0.6

0.5

0.4

0.3

0.2

0.1

0

Volts

Time

0

20

120

140

160

180

200

220

240

260

64

63

62

61

60

59

58

57

56

55

54

53

52

51

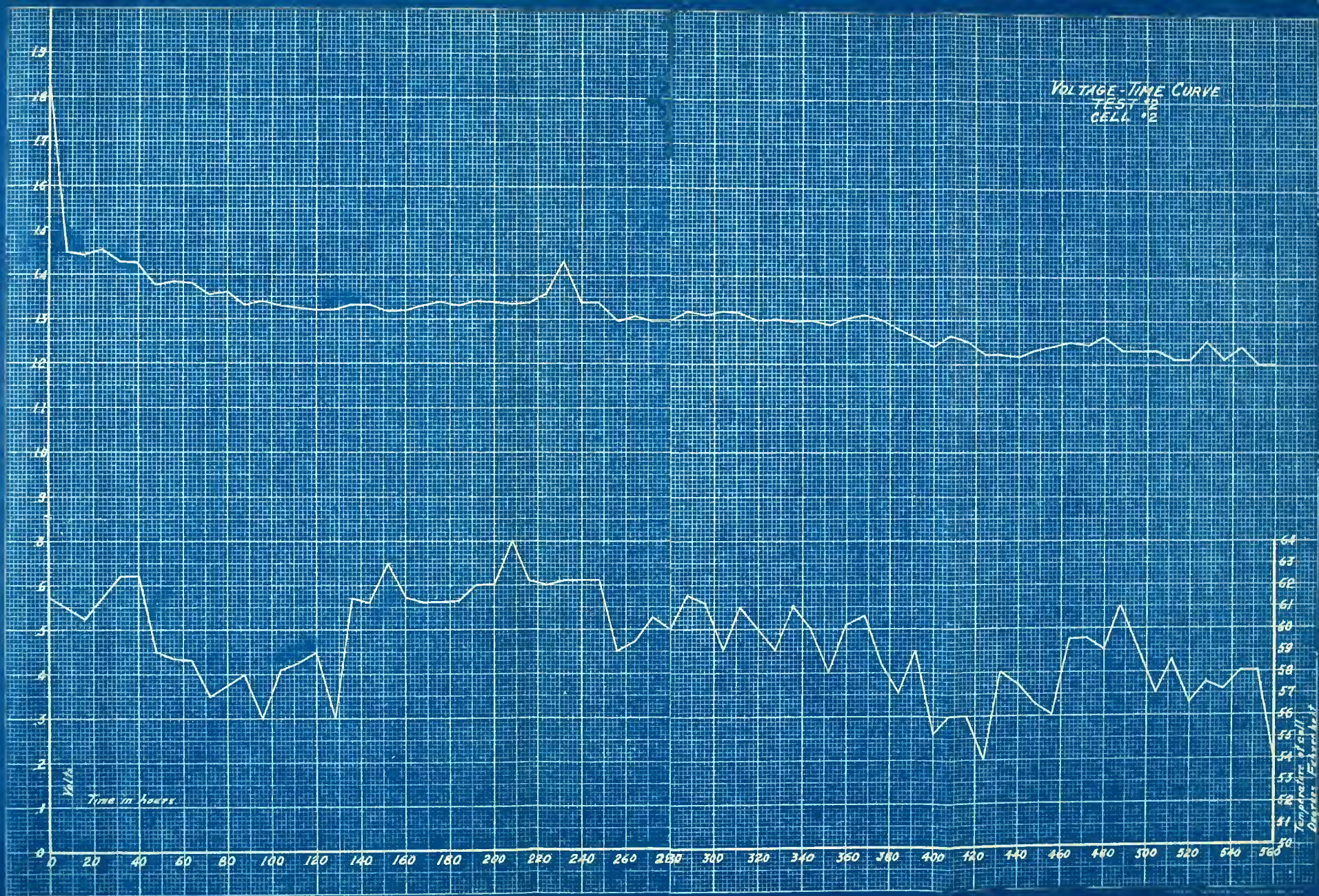
50

Temperature of cell
Degrees Fahrenheit

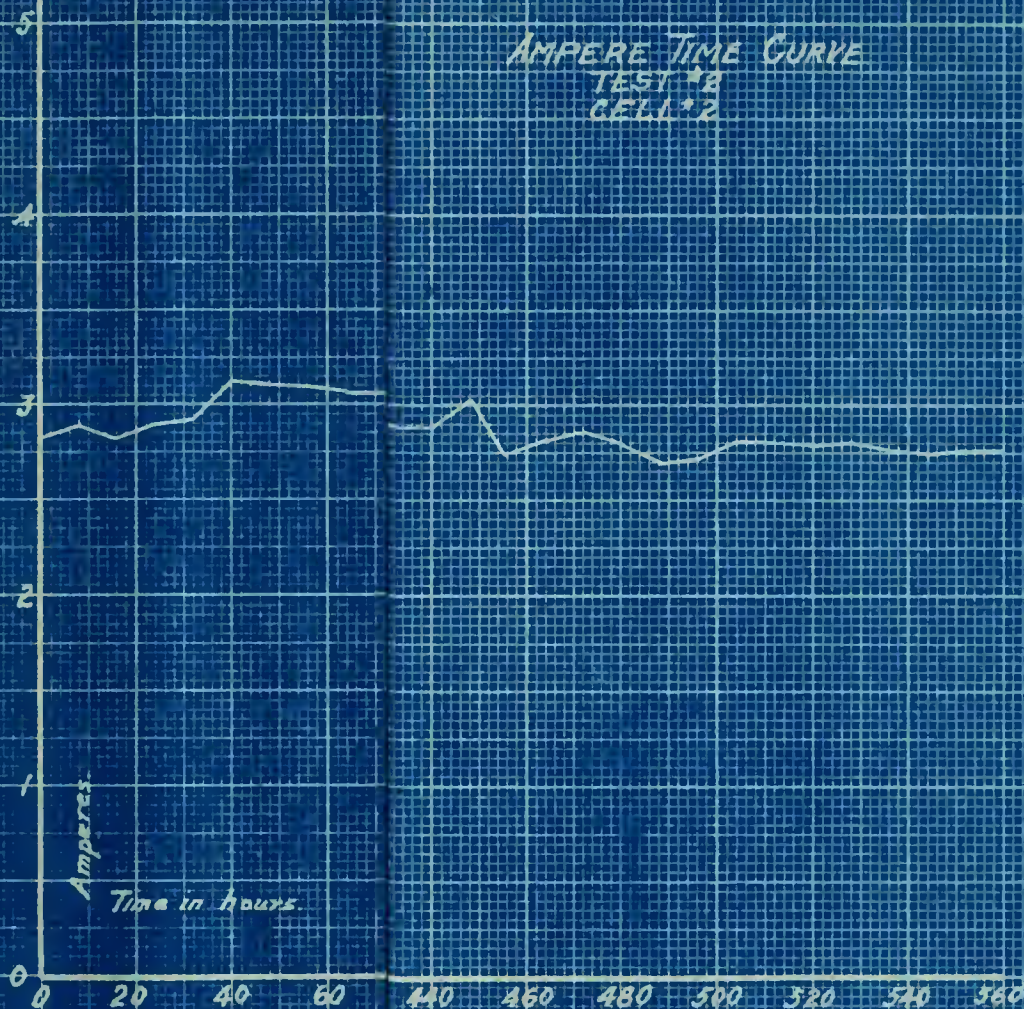
C E L I NO. II.

Time	E	I	Density	r	Wavelength
10 PM	1.21	1.252	2.80	26.5	1278
6 AM	1.21	1.242	2.73	27.1	1280
2 PM	1.30	1.237	2.80	27.1	1281
10 PM	1.21	1.252	2.71	27.1	1277
6 AM	1.24	1.276	2.7	27.4	1212
2 PM	1.2	1.252	2.76	27.4	122
10	1.2	1.236	2.71	26.1	124

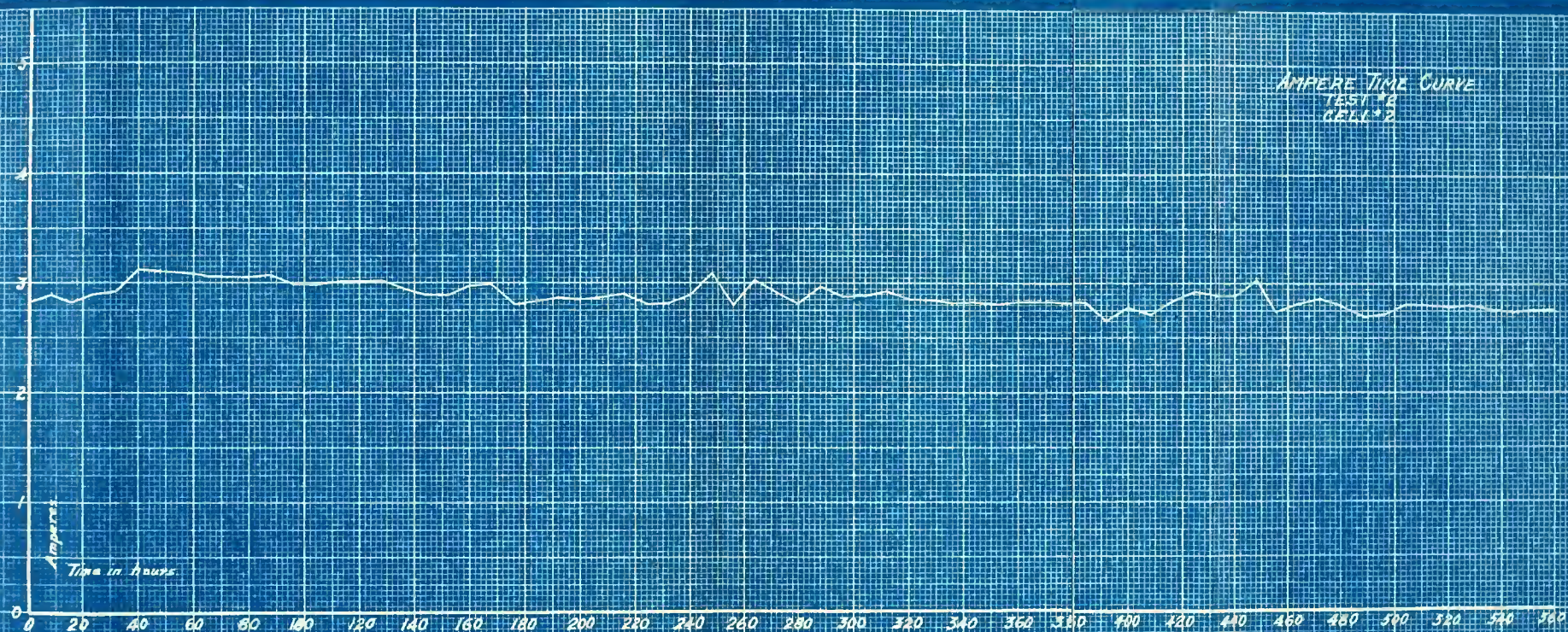
VOLTAGE-TIME CURVE
TEST #2
CELL #2



AMPERE TIME CURVE
TEST #2
CELL #2



AMPERE TIME CURVE
TEST 1
MAY 12



PART III.

Test # 3.

DISCHARGING CELL AT AN INTERMITTANT RATE.

PART III.

Test # 3.

DISCHARGING CELL AT AN INTERMITTENT RATE.

Test # 3.

Cell # 3.

In this test the cell was prepared and operated under practically the same conditions as cell # 2, with the exception that the value of the current was a little lower.

Curves were plotted as in previous tests, showing the variation in the value of amperes, volts and temperature with respect to time in hours. The same care was ^{taken} in obtaining the average values, as was previously exercised.

Calculations and Results.

Weight of zinc + mercury before test 6.0625 lbs.

Weight of zinc + mercury after test 5.663 lbs.

Weight of zinc consumed = .3995 lbs = 181.5 gms.

The number of hours in service was 560, the number of contacts was 16800 and the amp-hrs = 49×136.5 .

The theoretical value of the loss of zinc = $136.5 \times 3600 \times .000336 = 165.1$ gms. The zinc consumed by local action was 16.4 gms., giving an efficiency of 91.25 %.

Cost of Materials.

Weight of outer solution 6.739 lbs.

Weight of inner solution 3.536 lbs.

Total weight of solution 10.275 lbs.

Amount of acid in 10.275 lbs. of solution = 1.635 lbs.

H_2SO_4 consumed in the cell = $1.509 \times .3995 = .602$ lbs. of 100 % acid or .627 lbs. of commercial acid, and would

Test # 3.

Cell # 3.

In this test the cell was prepared and operated under practically the same conditions as cell #2, with the exception that the value of the current was a little lower.

Curves were plotted as in previous tests, showing the variation in the value of amperes, volts and temperature with respect to time in hours. The same care was taken in obtaining the average values, as was previously exercised.

Calculations and Results.

Weight of zinc + mercury before test 6.0635 lbs.
Weight of zinc + mercury after test 5.663 lbs.
Weight of zinc consumed = $3998 \text{ lbs} = 181.5 \text{ gms.}$
The number of hours in service was 760, the number of contacts was 16800 and the amp-hrs = $49 \times 136.5 = 6693.5$
The theoretical value of the loss of zinc = $136.5 \times 3600 \times .000336 = 165.1 \text{ gms.}$ The zinc consumed by local action was 16.4 gms., giving an efficiency of 91.25 %.

Cost of Materials.

Weight of outer solution 6.739 lbs.
Weight of inner solution 3.536 lbs.
Total weight of solution 10.275 lbs.
Amount of acid in 10.275 lbs. of solution = 1.635 lbs.
 H_2SO_4 consumed in the cell = $1.509 \times .3998 = .603 \text{ lbs. of}$
100 % acid or .627 lbs. of commercial acid, and would

cost .94 cents. KClO_3 consumed $= .418 \times .627 = .262$ lbs.
and costs 2.57 cents and zn consumed = 3.381cents.

The total cost of materials consumed allowing 80%
for chemicals used is 7.76 cts. for 178.2 watt-hrs. or
43.4 cts. per K.W.Hr.

cost 34 cents. 2013 contained = 1.14 x 1.05 = 1.197

and cost 3.57 cents 1.197 contained = 4.283 cents

The total cost of materials contained within 1.05

for operation is 1.197 + 3.083 = 4.280 cents

33.4 cents per A.W.Hr.

C E L L NO. III.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 AM		.16		15.		
1230 PM		1.82		16.5		
10 PM	1.456	1.746	2.51	16.	.111	8
6 AM	1.456	1.746	2.51	16.2	.111	16
2 PM	1.481	1.78	2.61	16.5	.114	24
10	1.481	1.776	2.6	16.5	.113	32
	14.4 oz. H ₂ O added					
6 AM	1.48	1.775	2.77	15.	.108	40
2 PM	1.43	1.741	2.83	16.1	.107	48
10	1.435	1.735	2.85	16.5	.105	56
6 AM	1.431	1.714	272	16.55	.104	64
2 PM	1.35	1.676	3.	16.8	.1068	72
10	1.355	1.68	3.1	16.7	.1045	80
6 AM	1.338	1.663	2.9	17.	.105	88
2 PM	1.378	1.664	2.69	17.5	.106	96
10	1.32	1.66	3.3	17.5	.103	104
6 AM	1.325	1.674	3.3	17.5	.104	112
2 PM	1.31	1.65	3.33	17.4	.103	120

III. 10. III.

Time	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
2 AM																								
3 AM																								
4 AM																								
5 AM																								
6 AM																								
7 AM																								
8 AM																								
9 AM																								
10 AM																								
11 AM																								
12 PM																								
1 PM																								
2 PM																								
3 PM																								
4 PM																								
5 PM																								
6 PM																								
7 PM																								
8 PM																								
9 PM																								
10 PM																								
11 PM																								
12 AM																								

C E L L NO. III.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
10 PM	1.31	1.65	3.33	18.5	.103	128
	3 oz.	H ₂ O added				
6 AM	1.33	1.66	3.1	17.5	.1062	136
2 PM	1.46	1.76	2.83	16.	.1058	144
10	1.34	1.65	2.9	16.6	.107	152
6 AM	1.361	1.651	2.83	17.	.1050	160
2 PM	1.3	1.594	2.89		.1019	168
10	1.32	1.636	2.93		.1072	176
6 AM	1.34	1.631	2.91		.1	184
2 PM	1.3	1.611	2.72		.1182	192
10	1.33	1.646	2.52		.1162	200
6 AM	1.36	1.66	2.71		.1108	208
	6 oz.	H ₂ O added				
2 PM	1.32	1.616	2.74		.1081	216
10	1.345	1.656	2.66	19.	.117	224
6 AM	1.33	1.634	2.66	19.	.1142	232
2 PM	1.315	1.646	2.82	19.5	.1174	240

C E I I No. III.

Time	E 1	E 2	I	Defect - 12	r	...
10 PM	1.31	1.63	1.33	18.5	101	103
	3.02	1.33				
6 AM	1.33	1.63	1.1	19.5	102	133
2 PM	1.33	1.76	2.87	16.	103	141
10	1.34	1.63	2.9	19.5	104	152
6 AM	1.35	1.63	2.63	17.	105	160
2 PM	1.3	1.34	2.89		106	168
10	1.33	1.33	2.93		107	179
6 AM	1.34	1.37	2.91		108	184
2 PM	1.3	1.31	2.73		109	193
10	1.33	1.34	2.63		110	200
6 AM	1.33	1.33	2.71		111	208
	3.02	1.33				
2 PM	1.33	1.36	2.74		112	212
10	1.34	1.33	2.66	13.	113	224
6 AM	1.33	1.34	2.66	19.	114	232
2 PM	1.35	1.34	2.37	19.3	115	240

C E L L NO. III.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
10 PM	1.318	1.614	2.81	19.9	.1055	248
6 AM	1.32	1.626	2.81	20.0	.1088	256
2 PM	1.32	1.636	2.73	21.	.1158	264
10 PM	1.31	1.626	2.66	21.	.1188	272
6 AM	1.31	1.616	2.68	21.4	.1143	280
2 PM	1.32	1.646	2.73	21.8	.1197	288
10	1.32	1.616	2.91	22.	.1018	296
6 AM	1.21	1.506	2.66	22.5	.1112	304
2 PM	1.26	1.586	2.74	22.7	.119	312
10	1.265	1.60	2.86	23.	.117	320
6 AM	1.26	1.591	2.79	23.2	.1185	328
2 PM	1.3	1.616	2.89		.1094	336
	6 oz. H ₂ O added					
10	1.3	1.606	2.99	23.2	.1023	344
6 AM	1.3	1.614	2.81	23.2	.1118	352
2 PM	1.3	1.596	2.75	23.2	.1078	360
10	1.255	1.596	2.86	23.5	.1192	368

Time	E 1	E 2	I	Partial- TV	r	Wrs.
10 PM	1.818	1.614	2.81	10.9	1.1052	318
9 AM	1.82	1.628	2.81	10.0	1.1028	322
3 PM	1.82	1.636	2.77	11.	1.1154	324
10 PM	1.81	1.622	2.66	11.	1.1158	328
9 AM	1.81	1.616	2.66	11.4	1.1148	330
3 PM	1.82	1.646	2.73	11.8	1.1184	332
10	1.82	1.616	2.91	12.	1.1012	336
9 AM	1.81	1.606	2.66	12.6	1.1118	344
3 PM	1.86	1.586	2.74	12.7	1.112	348
10	1.822	1.60	2.82	12.	1.117	350
9 AM	1.82	1.591	2.78	12.2	1.1182	352
3 PM	1.8	1.616	2.82		1.124	356
6 AM. No added						
10	1.8	1.606	2.92	12.2	1.1022	364
9 AM	1.8	1.614	2.91	12.2	1.1122	368
3 PM	1.8	1.596	1.75	12.2	1.1028	370
10	1.822	1.596	2.86	12.5	1.1122	372

C E L L NO. III.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
6 AM	1.24	1.58	2.86	23.6	.1188	376
2 PM	1.24	1.56	2.77	24.5	.1175	384
10	1.242	1.576	2.83	24.2	.118	392
6 AM	1.236	1.57	2.81	25.	.119	400
2 PM	1.236	1.57	2.81	25.1	.1188	408
10	1.24	1.576	2.82	25.8	.119	416
6 AM	1.25	1.566	2.65	25.9	.1192	424
2 PM	1.235	1.57	2.83	26.	.1182	432
10	1.23	1.56	2.82	26.3	.119	440
6 AM	1.22	1.571	2.72	26.6	.129	448
2 PM	1.25	1.574	2.51	26.8	.129	456
10	1.24	1.574	2.66	26.6	.1255	464
6 AM	1.24	1.574	2.69	27.3	.129	472
2 PM	1.22	1.576	2.76	27.5	.129	480
	6 oz. H ₂ O added.					
10	1.222	1.576	2.71	26.2	.1307	488
6 AM	1.23	1.566	2.56	26.8	.1312	496

TABLE NO. 111.

Time	T	S	I	Temp - °F	r	W.S.
6 AM	1.21	1.29	2.27	22.0	1112	372
8 AM	1.24	1.28	2.27	22.0	1117	384
10	1.242	1.273	2.27	22.0	1118	396
6 PM	1.282	1.27	1.27	22.1	1119	408
8 PM	1.282	1.27	2.27	22.1	1123	420
10	1.24	1.272	2.27	22.2	1125	432
6 AM	1.25	1.282	2.27	22.2	1127	444
8 PM	1.252	1.27	1.28	22.1	1128	456
10	1.23	1.28	2.28	22.2	1129	468
6 AM	1.23	1.271	2.28	22.2	1130	480
8 PM	1.23	1.272	2.28	22.2	1131	492
10	1.24	1.274	2.28	22.2	1132	504
6 AM	1.24	1.274	2.28	22.2	1133	516
8 PM	1.23	1.272	2.28	22.2	1134	528
No. added.						
10	1.232	1.276	2.27	22.2	1135	540
6 PM	1.23	1.282	2.28	22.2	1136	552

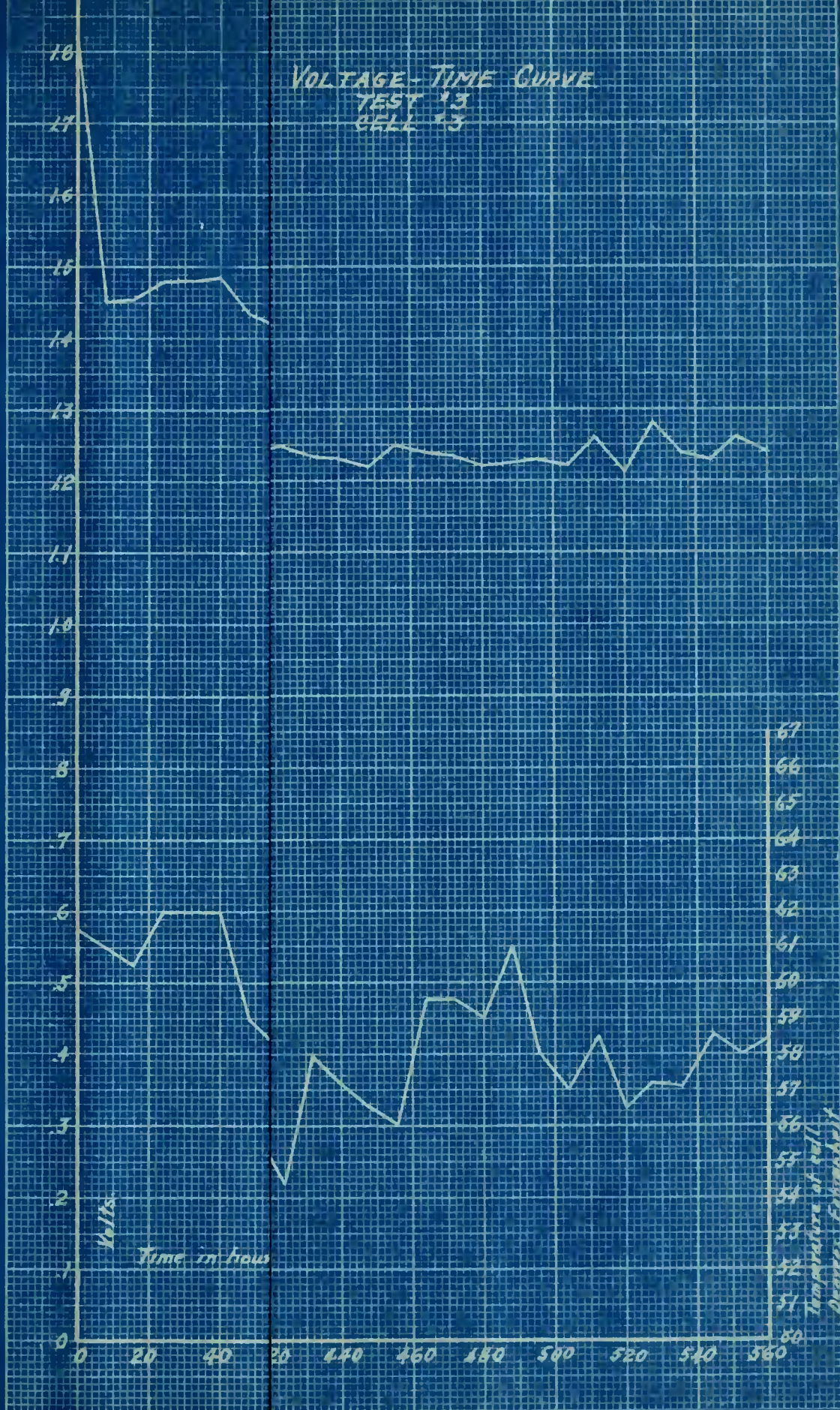
C E L L NO. III.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 PM	1.22	1.556	2.54	26.8	.1345	504
10	1.26	1.556	2.53	27.5	.133	512
6 AM	1.21	1.556	2.51	28.	.138	520
2 PM	1.28	1.646	2.73	28.4	.1376	528
10	1.24	1.606	2.51	27.4	.138	536
6 AM	1.23	1.584	2.56	28.	.1382	544
2 PM	1.26	1.57	2.41	28.	.1289	552
10	1.24	1.534	2.11	28.8	.139	560

G L I I No. 111.

Time	I	II	III	IV	V	VI
3 PM	1.33	1.33	1.33	1.33	1.33	1.33
10	1.33	1.33	1.33	1.33	1.33	1.33
8 AM	1.31	1.31	1.31	1.31	1.31	1.31
3 PM	1.33	1.33	1.33	1.33	1.33	1.33
10	1.33	1.33	1.33	1.33	1.33	1.33
9 PM	1.33	1.33	1.33	1.33	1.33	1.33
3 PM	1.33	1.33	1.33	1.33	1.33	1.33
10	1.33	1.33	1.33	1.33	1.33	1.33

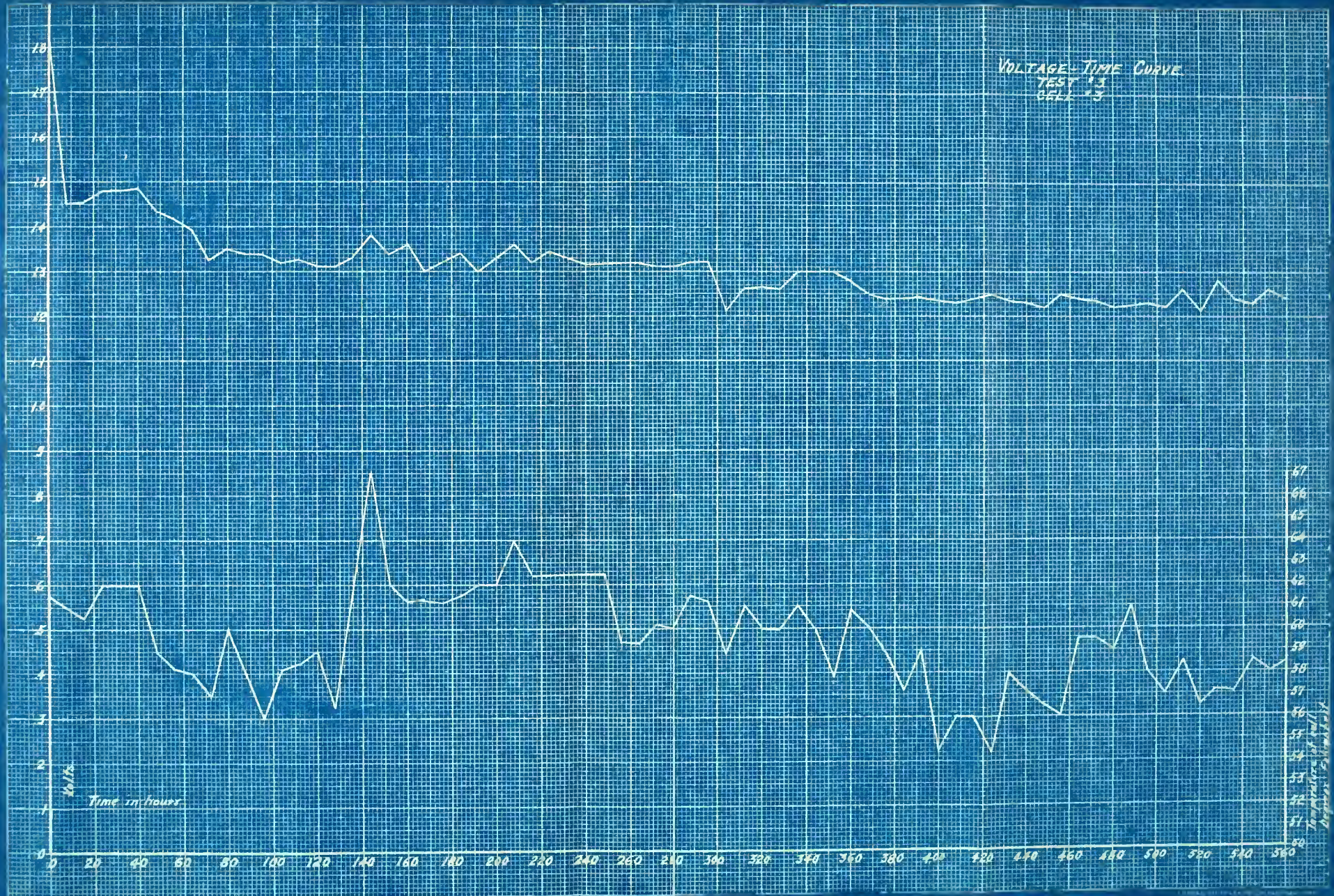
VOLTAGE-TIME CURVE TEST 13 CELL 13



C E L I M. III.

Time	I	II	III	IV	V
2 PM	1.12	1.55	2.24	2.53	3.22
10	1.26	1.55	2.24	2.53	3.22
8 AM	1.21	1.55	2.24	2.53	3.22
2 PM	1.23	1.55	2.24	2.53	3.22
10	1.24	1.55	2.24	2.53	3.22
8 AM	1.23	1.55	2.24	2.53	3.22
2 PM	1.23	1.55	2.24	2.53	3.22
10	1.24	1.55	2.24	2.53	3.22

VOLTAGE-TIME CURVE
TEST 13
CELL 13



AMPERE TIME CURVE
TEST #3
CELL #3

Amperes

Time in hours

4

3

2

1

0

0

20

40

60

440

460

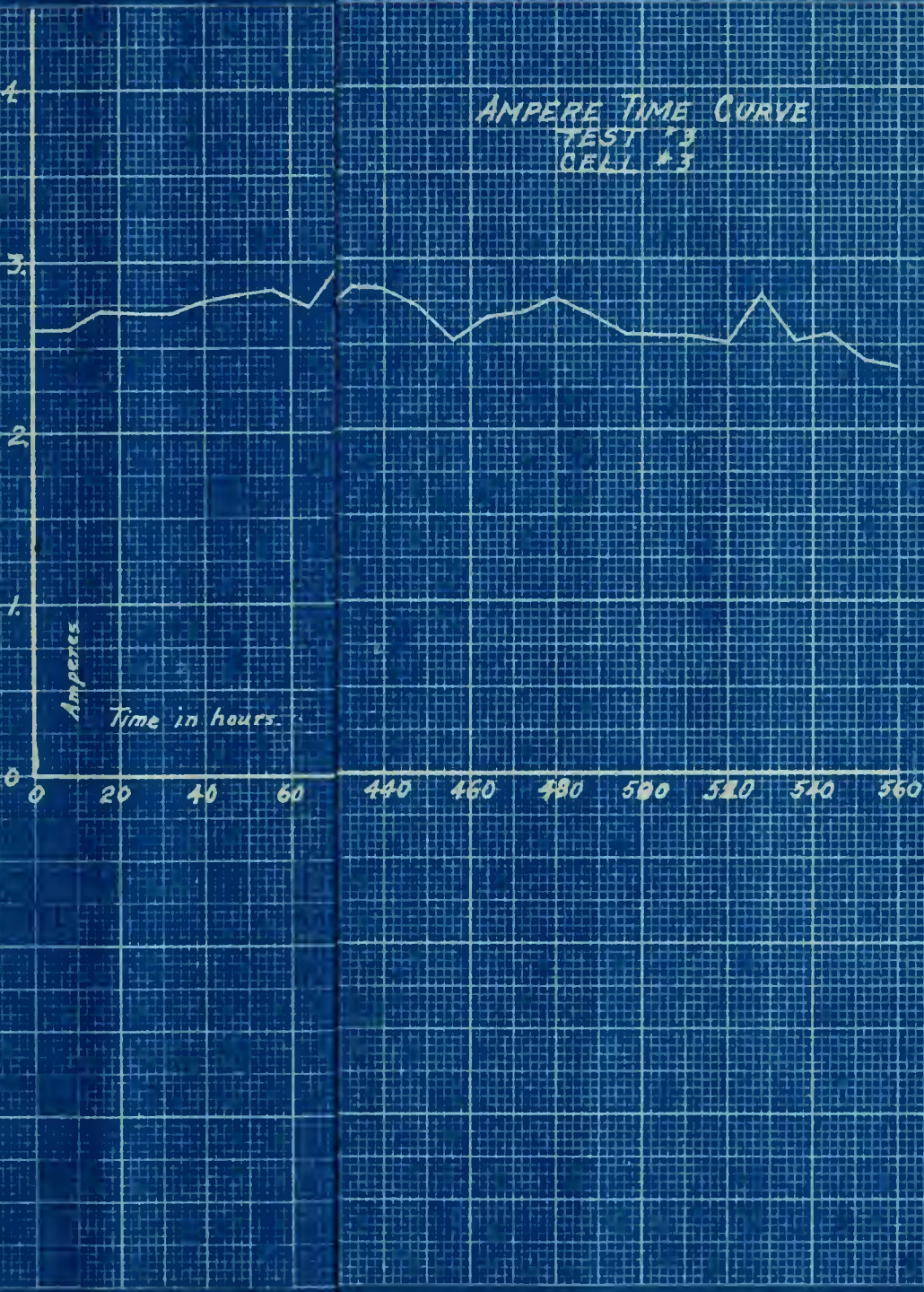
480

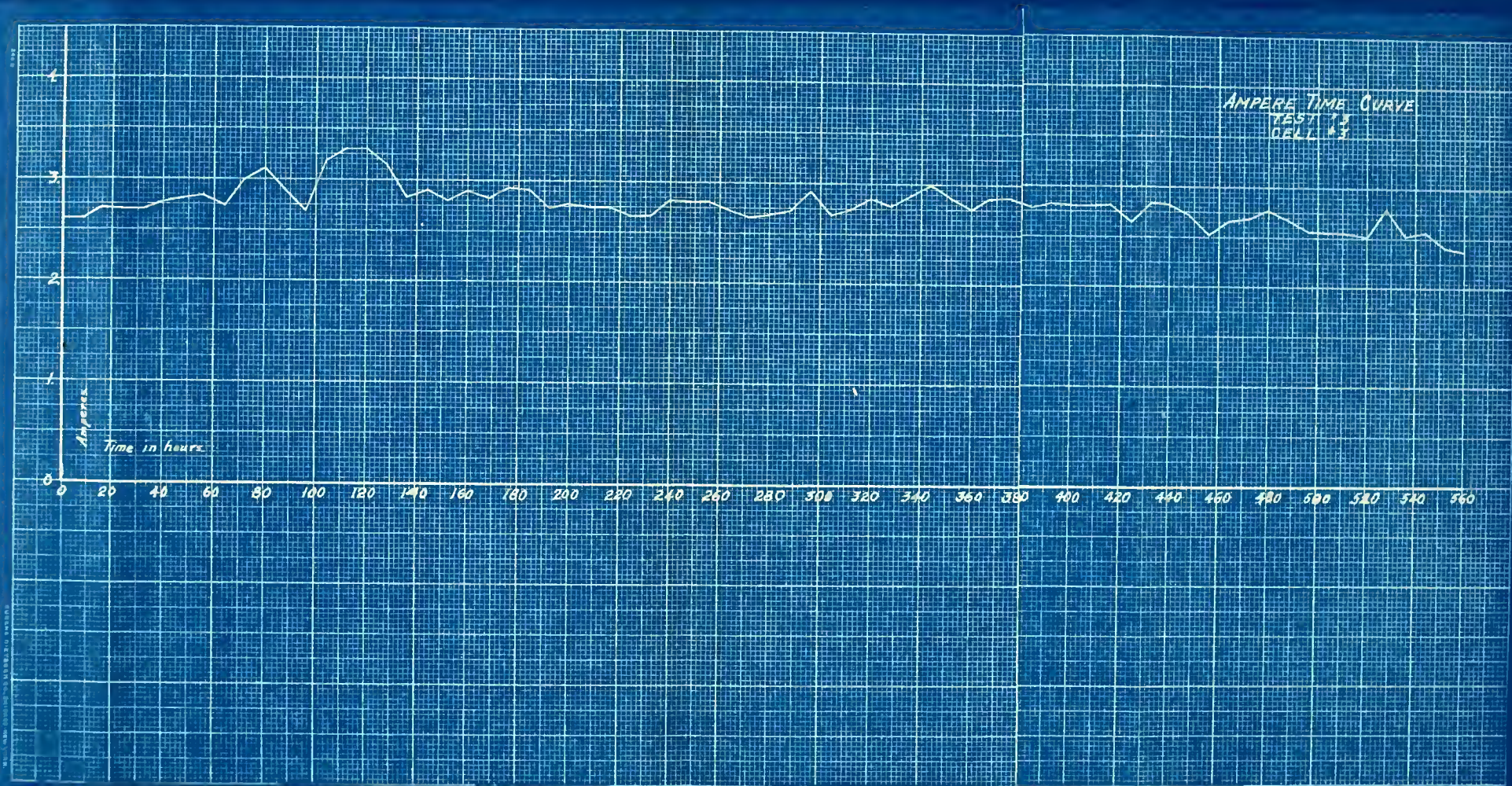
500

520

540

560





PART IV.

TEST # 4.

TEST OF A COPPER SULPHATE CELL.

PART IV.
TEST N. 4.
TEST OF A COPPER SULPHATE CELL.

Part IV.

Test # 4.

In this test a copper sulphate cell was used. The cell was prepared by placing the copper electrode in the bottom of the jar and placing 1.5 lbs. of pulverized copper sulphate or "blue stone" in cell and then filling jar to within .5 inches of the top. The cell was then short circuited for 12 hours to secure a normal condition of operation. The weight of each part entering into the construction of the cell was carefully ascertained.

The current, voltage, and temperature were observed at the same time as these quantities were observed of the other cells.

Curves were plotted showing the value of these quantities with respect to time. The areas of the curves were determined with a planimeter and the average values determined therefrom.

Calculations and Results.

Weight of zn consumed was 1.472 lbs or 668 gms. The theoretical value of the zn consumed is $89.4 \text{ amp-hrs} \times 3600 \times .000336 = 108 \text{ gms.}$

The zn evidently consumed by local action was 560 gms., giving an efficiency of 16.2%.

Cost of Materials.

Cost of zn at 7cts. per lb was 12.9 cts. and cost

Part IV.

Test # 4.

In this test a copper sulphate cell was used. The cell was prepared by placing the copper electrode in the bottom of the jar and placing 1.5 lbs. of pulverized copper sulphate or "blue stone" in cell and then filling jar to within 5 inches of the top. The cell was then short circuited for 18 hours to secure a normal condition of operation. The weight of each part entering into the construction of the cell was carefully ascertained.

The current, voltage, and temperature were observed at the same time as these quantities were observed of the other cells.

Curves were plotted showing the value of these quantities with respect to time. The areas of the curves were determined with a planimeter and the average values determined therefrom.

Calculations and Results.

Weight of Zn consumed was 1.473 lbs or 668 gms. The theoretical value of the Zn consumed is 89.4 gms. $668 \times .000356 = 108 \text{ gms.}$

The Zn actually consumed by local action was 668 gms., giving an efficiency of 16.2%.

Cost of Materials.

Cost of Zn at 70¢. per lb was 12.9 ¢. and cost

of copper sulphate at 7 cts.per lb. was 10.5 cts,
giving a total cost of 23.4 cts. for 25.5 watt-hrs.
or \$9.17 per K.W.Hr.

of copper sulphate at 7 cts. per lb. was 10.5 cts.,
giving a total cost of \$3.4 cts. for 33.5 watt-hrs.
or \$9.17 per K.W.Hr.

C E I L NO. IV.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2PM	.35	1.1	.285		2.57	8
10	.34	1.1	.266		2.75	16
6 AM	.34	1.1	.269		2.75	24
2 PM	.32	1.1	.269		2.78	32
10	.19	.99	.246		3.26	40
6 AM	.314	1.1	.23		3.	48
2 PM	.318	1.1	.227		3.49	56
10	.321	1.1	.233		3.35	64
6 AM	.329	1.15	.22		3.49	72
2 PM	.342	1.08	.235		3.26	80
10	.33	1.08	.222		2.96	88
6 AM	.33	1.06	.244		2.99	96
2 PM	.395	1.08	.26		2.64	104
10	.31	1.03	.25		2.88	112
6 AM	.31	.99	.23		3.05	120
2 PM	.31	1.01	.25		2.84	128

VI. 1900 - 1900

TIME	DATE	PLACE	1	2	3	THAT
8	1900		100.	1.1	60.	100
01	1900		100.	1.1	60.	01
02	1900		100.	1.1	60.	MA 0
03	1900		100.	1.1	60.	MA 0
04	1900		100.	1.1	60.	01
05	1900		100.	1.1	60.	01
06	1900		100.	1.1	60.	01
07	1900		100.	1.1	60.	01
08	1900		100.	1.1	60.	01
09	1900		100.	1.1	60.	01
10	1900		100.	1.1	60.	01
11	1900		100.	1.1	60.	01
12	1900		100.	1.1	60.	01
13	1900		100.	1.1	60.	01
14	1900		100.	1.1	60.	01
15	1900		100.	1.1	60.	01
16	1900		100.	1.1	60.	01
17	1900		100.	1.1	60.	01
18	1900		100.	1.1	60.	01
19	1900		100.	1.1	60.	01
20	1900		100.	1.1	60.	01
21	1900		100.	1.1	60.	01
22	1900		100.	1.1	60.	01
23	1900		100.	1.1	60.	01
24	1900		100.	1.1	60.	01
25	1900		100.	1.1	60.	01
26	1900		100.	1.1	60.	01
27	1900		100.	1.1	60.	01
28	1900		100.	1.1	60.	01
29	1900		100.	1.1	60.	01
30	1900		100.	1.1	60.	01

C E L L NO. IV.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
10 PM	.28	1.	.252		2.86	136
6 AM	.30	.96	.225		3.07	144
2 PM	.25	.92	.215		3.12	152
10	.25	.92	.215		3.12	160
6 AM	.24	.91	.214		3.15	168
2 PM	.243	.913	.215		3.02	176
10	.24	.90	.215		3.12	184
6 AM	.22	.89	.22		2.96	192
2 PM	.268	.91	.23		2.82	200
10	.22	.89	.22		2.98	208
6 AM	.22	.88	.22		3.00	216
2 PM	.315	.96	.233		2.92	224
10	.32	.97	.22		2.95	232
6 AM	.31	.965	.23		2.90	240
2 PM	.31	.964	.235		2.90	248
10	.315	.97	.23		2.84	256
6 AM	.29	.95	.228		2.9	264

CHIEF OF POLICE

Time	1	2	3	4	5	6
10 PM	88.	88.	88.	88.	88.	88.
9 PM	88.	88.	88.	88.	88.	88.
8 PM	88.	88.	88.	88.	88.	88.
7 PM	88.	88.	88.	88.	88.	88.
6 PM	88.	88.	88.	88.	88.	88.
5 PM	88.	88.	88.	88.	88.	88.
4 PM	88.	88.	88.	88.	88.	88.
3 PM	88.	88.	88.	88.	88.	88.
2 PM	88.	88.	88.	88.	88.	88.
1 PM	88.	88.	88.	88.	88.	88.
12 PM	88.	88.	88.	88.	88.	88.
11 AM	88.	88.	88.	88.	88.	88.
10 AM	88.	88.	88.	88.	88.	88.
9 AM	88.	88.	88.	88.	88.	88.
8 AM	88.	88.	88.	88.	88.	88.
7 AM	88.	88.	88.	88.	88.	88.
6 AM	88.	88.	88.	88.	88.	88.
5 AM	88.	88.	88.	88.	88.	88.
4 AM	88.	88.	88.	88.	88.	88.
3 AM	88.	88.	88.	88.	88.	88.
2 AM	88.	88.	88.	88.	88.	88.
1 AM	88.	88.	88.	88.	88.	88.
12 AM	88.	88.	88.	88.	88.	88.

C E L L NO. IV.

Time	E 1	E 2	I	Densi- ty	r	Hrs.
2 PM	.27	.93	.22		3.	272
10	.28	.94	.22		3.02	280
6 AM	.275	.95	.22		3.06	288
2 PM	.30	.975	.24		2.81	296
10	.29	.96	.22		3.06	304
6 AM	.28	.93	.215		3.03	312
2 PM	.24	.89	.215		3.03	320
10	.21	.88	.22		3.04	328
6 AM	.198	.83	.221		3.	336
2 PM	.26	.83	.2		2.95	344
10	.16	.78	.19		3.26	352
6 AM	.11	.52	.125		3.35	360

TABLE IV.

Time	W I	E S	I	Density	r	Sta
3 PM	.27	.29	.32		.2	272
10	.28	.24	.32		.302	280
6 AM	.275	.25	.25		.202	282
3 PM	.30	.275	.24		.202	282
10	.29	.25	.25		.202	284
6 AM	.28	.25	.215		.202	285
3 PM	.24	.25	.215		.202	285
10	.21	.25	.25		.202	285
6 AM	.198	.25	.251		.2	285
3 PM	.25	.25	.2		.202	287
10	.16	.28	.19		.202	287
6 AM	.11	.25	.152		.202	287

E CURVE

4

3

2

1

Amps

Time in hours

0

0

20

40

60

80

100

120

320

340

360

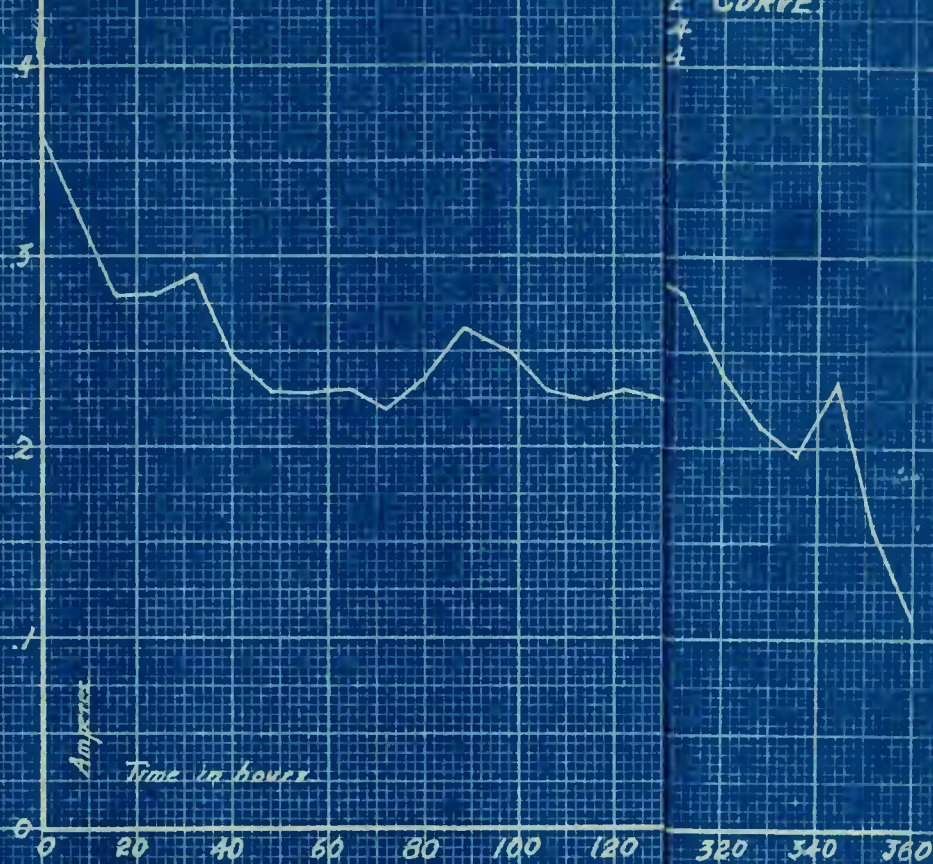
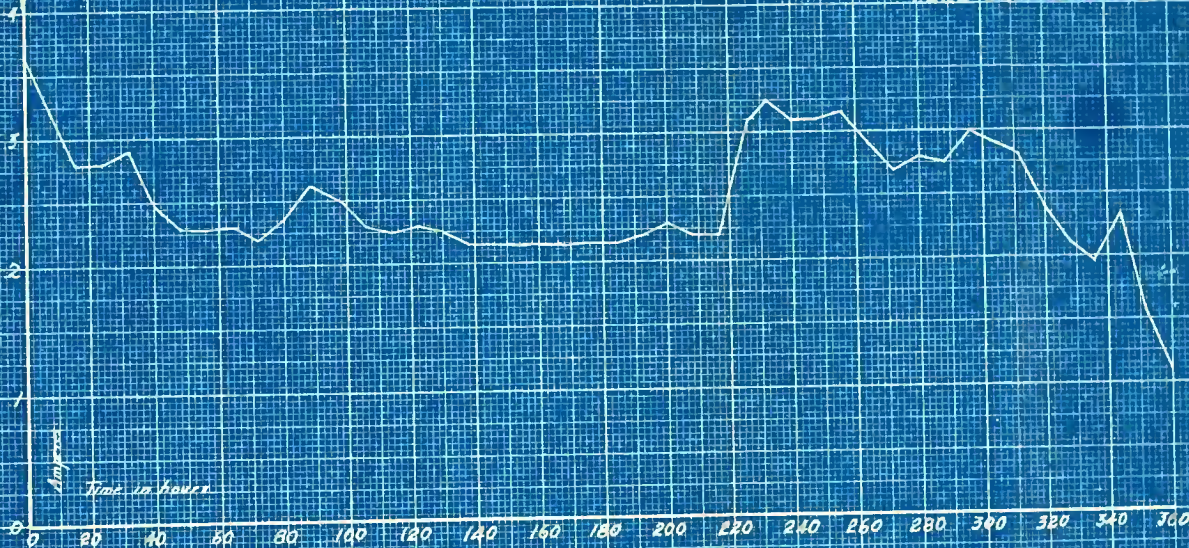
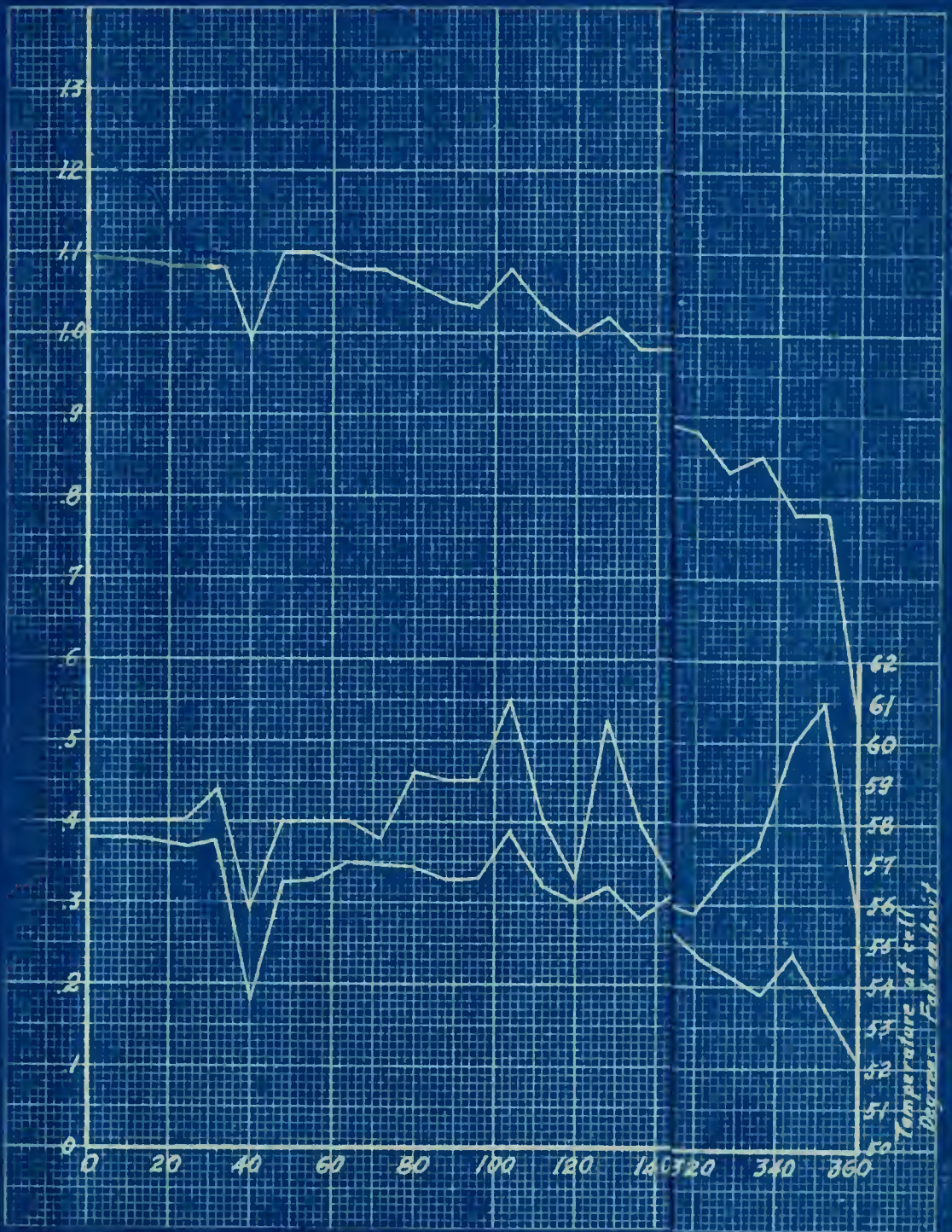


TABLE IV.

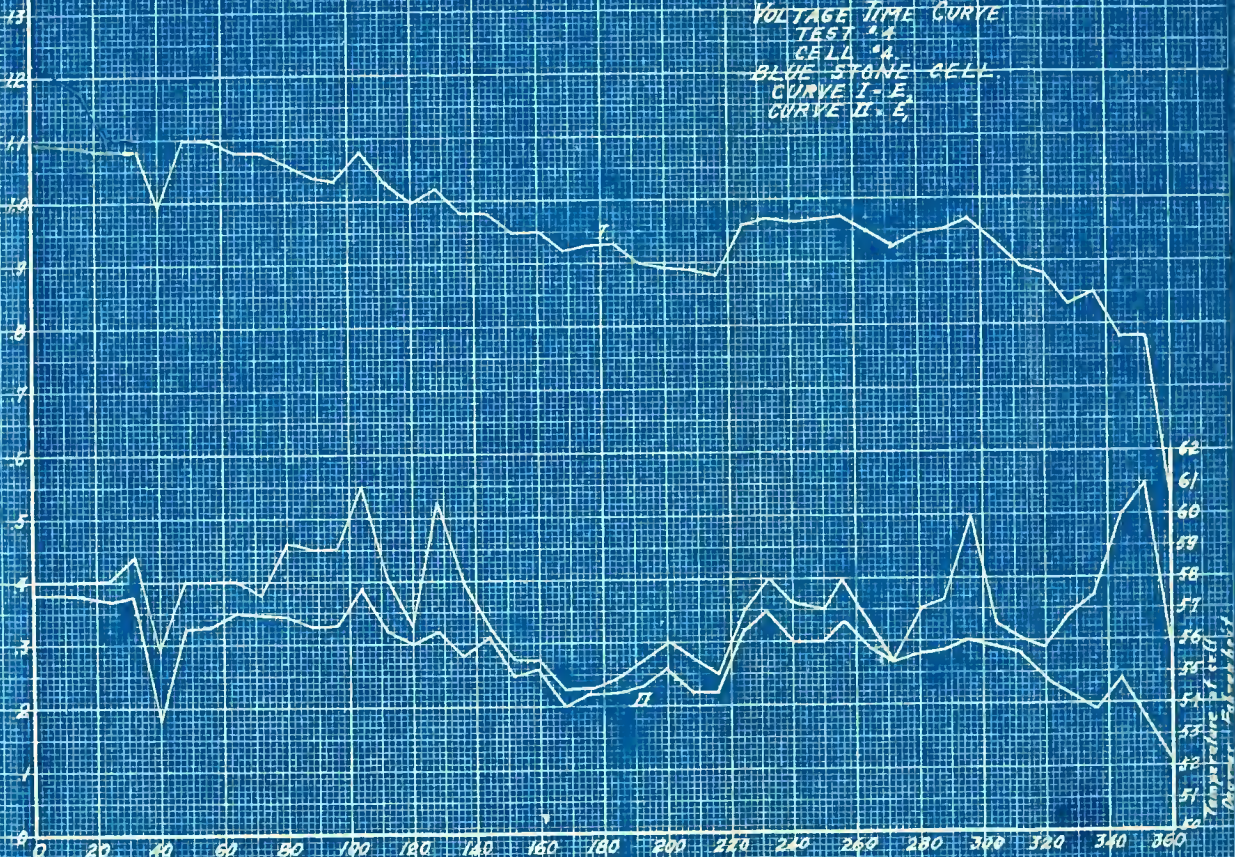
Time	1	2	3	4	5	6
8 PM	27.	29.	32.	35.	38.	41.
10	28.	30.	33.	36.	39.	42.
6	27.5	29.	32.	35.	38.	41.
8 PM	28.	30.	33.	36.	39.	42.
10	28.	30.	33.	36.	39.	42.
6 AM	28.	30.	33.	36.	39.	42.
8 PM	28.	30.	33.	36.	39.	42.
10	28.	30.	33.	36.	39.	42.
6 AM	28.	30.	33.	36.	39.	42.
8 PM	28.	30.	33.	36.	39.	42.
10	28.	30.	33.	36.	39.	42.
6 AM	28.	30.	33.	36.	39.	42.

AMPERE TIME CURVE
TEST #4
CELL #4





VOLTAGE TIME CURVE
 TEST #4
 CELL #4
 BLUE STONE CELL.
 CURVE I - E,
 CURVE II - E,



PART IV.

SUMMATION AND DISCUSSION OF RESULTS.

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The highest voltage obtained in this series of tests was 1.832 volts. A greater voltage would evidently have been secured if the temperature had been a little higher.

From a consideration of the cost of materials it will be noted that cell # 2 gave the greatest watt-hour output in the given time. Cell # 1 gave a watt-hr. output 181.2 watt-hrs. at a cost of 39.75 cts. per K.W. Hr. for energy: cell # 2 gave 186 watt-hrs. at a cost of 43.1 cts. per K.W.Hr. for energy: cell #3 gave 178.2 watt-hrs. at a cost of 43.4 cts per K.W.Hr and the copper sulphate cell gave 25.5 watt-hrs. at a cost of \$9.17 per K.W.Hr.

Referring to the volt-time curve it will be noted that cell # 1 maintained an average current of .2097 amperes for 560 hours, with a voltage variation of 17.2 %. The value of the current was maintained with a variation of only 11.1 % with a temperature variation of 8 deg. Centigrade.

Cell # 2 maintained an average current of 2.88 amperes for 560 hours with a voltage variation, figuring from the time the cell action became stable, of 16.08 % and a current variation of 17.2 % with

Summation and Discussion of Results.

The highest voltage obtained in this series of tests was 1.832 volts. A greater voltage would evidently have been secured if the temperature had been a little higher.

From a consideration of the cost of materials it will be noted that cell # 2 gave the greatest watt-hour output in the given time. Cell # 1 gave a watt-hour output of 181.2 watt-hrs. at a cost of 39.73 cts. per K.W. Hr. for energy; cell # 2 gave 180 watt-hrs. at a cost of 43.1 cts. per K.W. Hr. for energy; cell # 3 gave 178.2 watt-hrs. at a cost of 43.4 cts. per K.W. Hr. and the copper sulphate cell gave 22.2 watt-hrs. at a cost of \$9.17 per K.W. Hr.

Referring to the volt-time curve it will be noted that cell # 1 maintained an average current of .2097 amperes for 560 hours, with a voltage variation of 17.2%. The value of the current was maintained with a variation of only 11.1% with a temperature variation of 8 deg. Centigrade.

Cell # 2 maintained an average current of 2.88 amperes for 560 hours with a voltage variation of 17.2% and a current variation of 16.8% with a variation of 17.2%.

a temperature variation of 8 deg.C.

Cell #3 maintained an average current of 2.783 amperes and a potential of 1.305 volts, for a period of 560 hours, with a voltage variation of 17.81 % and a current variation of 15.8 % , with a temperature variation of 8 deg.C. This was obtained after the action of the cell had become normal and the resistance properly adjusted.

Cell # 4 did not give a very steady value of voltage or current and was greatly affected by the temperature, while the other three cells were not so greatly affected by changes in temperature. This is readily explained by the fact that the resistance of the potassium chlorate cells varied from a minimum of .106 ohms to a maximum of .246 ohms, while the resistance of the copper sulphate cell varied from 2.57 to 3.35 ohms.

It is evident from a consideration of the cost of materials and watt-output that it costs slightly less to operate the cell at a low rate of discharge than at a high rate of discharge.

From a consideration of the above results it is obvious, that as cell # 2 gave an average discharge of 3.8 watts per second, that it would require 53 copper cells to do the work of one $KClO_3$ cell.

a temperature variation of 8 deg. C.

Cell #3 maintained an average current of 2.785

amperes and a potential of 1.305 volts, for a period of

500 hours, with a voltage variation of 17.81 mV and a

current variation of 15.8 mV, with a temperature

variation of 8 deg. C. This was obtained after the

action of the cell had become normal and the resistance

properly adjusted.

Cell #4 did not give a very steady value of

voltage or current and was greatly affected by the

temperature, while the other three cells were not

so greatly affected by changes in temperature.

This is readily explained by the fact that the resist-

ance of the potassium chlorate cells varied from a

minimum of .108 ohms to a maximum of .246 ohms, while

the resistance of the copper sulphate cell varied

from 2.57 to 3.35 ohms.

It is evident from a consideration of the cost of

materials and watt-output that it costs slightly less

to operate the cell at a low rate of discharge than at

a high rate of discharge.

From a consideration of the above results it is

obvious, that as cell #2 gave an average discharge

of 3.6 watts per second, that it would require 50

copper cells to do the work of one KClO₃ cell.

From a final survey of the possibilities of this cell, it appears that there is an extensive field in which the KClO_3 cell might replace those at present in use, with an enormous saving in cost.

From a final survey of the possibilities of this cell, it appears that there is an extensive field in which the KOLG cell might replace those at present in use, with an enormous saving in cost.

